MOTOR WINDING PRACTICE

Instructional-cum-Practical Manual

for

Repair, Maintenance and Rewinding of

Electrical Motors (Class XII)

SACHCHINDANANDA RAY
Project Coordinator

राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद्
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FOREWORD

The programme of vocationalization of higher secondary education has been accepted by the country as it holds forth great promise for linking education with the productivity and economic development of the country.

In view of the importance of the programme, the NCERT is making an all-out effort to provide academic support to the implementing agencies in the States. One of the major contributions of the NCERT is in the field of curriculum development and in the development of model instructional materials. The materials are developed through workshops in which experts, subject specialists, employees' representatives, curriculum framers and teachers of vocational courses are involved.

The present manual Motor Winding Practice has been developed in the manner described above and is meant for the students studying Repair, Maintenance and Rewinding of Electrical Motors (Class XII) and allied vocations. It is being published for wider dissemination amongst students and teachers throughout the country. I hope that they will find the manual useful.

I am grateful to all those who have contributed to the development of this manual. I must acknowledge the role played by Professor A. K. Mishra, Head, Department of Vocationalization of Education, in inspiring his colleagues in their endeavours to develop this instructional material. Shri S. Ray, Senior Lecturer who functioned as the Project Coordinator for developing this title, deserves special mention for the efforts he put in to bring out this publication.

We would welcome suggestions for improvement of this manual.

(Dr) K. Gopalan
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New Delhi
January 1993

PREFACE

Ever since the introduction of vocationalization in our school system by several States and Union Territories of our country the paucity of appropriate instructional materials has been felt as one of the major constraints in the implementation of the programme and also as a source of great hardship to the pupils offering vocational studies at the higher secondary stage.

The Department of Vocationalization of Education of the National Council of Educational Research and Training (NCERT) has started a modest programme of developing instructional materials of diverse types to fill up this void in all major areas of vocational education. The task is too gigantic to be completed by any single agency but the model materials being developed by us might provide guidance and impetus to the authors and agencies desiring to contribute in this area. These are based on the national guidelines developed by a Working Group of experts constituted by the NCERT.

The present manual Motor Winding Practice is meant for the pupils and teachers teaching Repair, Maintenance and Rewinding of Electrical Motors (Class XII) and allied vocations being offered in a number of States. It contains activities (Practical Exercises) to be performed by pupils with simple steps to follow, precautions to be taken and data to be recorded and processed. Each activity is complete with objective, relevant information, procedure, evaluation, etc. It is hoped that the users will find them immensely useful.

The experimental edition of the manual was developed by a group of experts in a workshop held at the Industrial Training Institute, Aundh-Pune. The manual was reviewed during the workshop.

The names of the contributors and reviewer are mentioned elsewhere and their contributions are admirably acknowledged. Shri S. Ray, co-ordinator of this project, deserves special thanks for editing, reviewing and bringing out the manual in the present form. The assistance of all in the Industrial Training Institute, Aundh-Pune and the Department of Vocationalization of Education, NCERT, is also thankfully acknowledged.

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Reviewer

Shri Sachchidananda Ray

GANDHIJI'S TALISMAN

"I will give you a talisman. Whenever you are in doubt or when the self becomes too much with you, apply the following test :

Recall the face of the poorest and the weakest man whom you may have seen and ask yourself if the step you contemplate is going to be of any use to him. Will he gain anything by it ? Will it restore him to a control over his own life and destiny ? In other words, will it lead to Swaraj for the hungry and spiritually starving millions ?

Then you will find your doubts and your self melting away."

M K Gandhi

ABOUT THE MANUAL

Under the programme of Vocationalization of Education about fifty different vocational courses in the area of engineering and technology have been introduced by seventeen States and four Union Territories so far. These courses are running for the last about thirteen years. From the beginning, the Department of Vocationalization of Education of the NCERT has been working hand in hand with the State organisations concerned, through various programmes organised for State officials, vocational teachers and others. In fact by now the Department has conducted on-the-spot studies of the vocational programme in a large number of States to find out the mertis and demerits of the programme and to suggest appropriate measures to resolve the problems in enginnering and technical vocational education. These programmes have revealed that there was a great dearth of suitable instructional materials and the need for practical manual, especially, was urgently felt. The development of instructional materials and the imparting of practical training become even more important when one considers the purpose for which Vocationalization of Education was launched. The main aim of the programme was to prepare the pupil for purposeful and gainful employment (wage-employment or self-employment).

The Department constituted a Working Group in 1982 to formulate guidelines for models of a variety of instructional materials.

Based on the guidelines formulated by the Working Group, 'Repair, Maintenance and Rewinding of Electrical Motors' was selected by the Department for the purpose of development of instructional materials in a phased manner. To begin with, the development of instructional-cum-practical manuals has been taken up.

The content of the 'Repair, Maintenance and Rewinding of Electrical Motors' course was thoroughly analysed and it was felt that six manuals would be necessary to cater to the needs of the course. The present manual Motor Winding Practice is one of them. This manual is intended to help both teachers and pupils. Each activity is complete with specific objectives, related information, equipment and materials, procedure, observations, precautions and questions for evaluation. In order to acquaint the pupils with each activity, the teacher should provide them with required theoretical knowledge or information related to the activity. This will help the pupils in acquiring proper understanding of the activity and enable them to perform the activity properly and effectively.

In order to meet the stipulated objectives, the activities include the study and operation of the tools and instruments which an electric motor repairer would be required to use in his professional career.

The evaluation of the activities performed by the pupils shall be based on specific objectives. The teacher shall evaluate all the aspects which are relevant to achieve the specific objectives. This will contribute towards the 'expected behavioural outcome'. Evaluation is an important aspect of performing the activities.

Each activity should be assessed through evaluation based on knowledge, acquired skills and competencies, attitude and aptitude towards work, activity performance, application and maintenance of activity record.

Tabular representation of the suggested evaluation scheme is as follows:

Sl. No.	*Components*	*Marks obtained*	*Marks awarded*
(i)	Knowledge	20	
(ii)	Acquired skills and competencies	35	
(iii)	Attitude and aptitude towards work	15	
(iv)	*Activity performance*	*10*	
(v)	Application	10	
(vi)	Maintenance of activity record	10	
	Total marks	100	

At the end of each activity, some questions for evaluation are given. The pupils shall answer these questions on the completion of each activity and teacher shall examine them. If required, necessary corrections and suitable suggestions should be incorporated by the teacher. However, the answers to these questions should not be considered for the purpose of awarding final grade.

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ACTIVITY NO. 1

Dismantling of an A.C. Motor

Specific Objectives

(i) To dismantle A.C. single phase motor.
(ii) To dismantle A.C. three phase motor.
(iii) To note down name plate details of A.C. motor.
(iv) To note down winding details of A..C. motor.

Related Information

When a motor fails to run properly, certain definite procedure should be followed for confirming the repairs or rewinding of motor. Physical inspection and series of tests, such as insulation test and earth fault test are to be conducted to find out exact fault.

Usually the single-phase (split-phase or fractional horse power) motor has four main parts : rotor, stator, end plates and centrifugal switch. This is illustrated in Fig. 1.1. The rotor consists of shaft, laminated core and rotating part of centrifugal switch. The stator consists of laminated iron core having slots and is mounted inside an iron frame. The core accomodates two windings such as starting and running winding. These windings are connected to supply when the motor is started. Once the motor attains predetermined speed, the starting winding is automatically disconnected from supply through centrifugal switch. The end plates are fastened to stator frame and accomodates bearings in it. Rotor shaft rests in the bearings. In case of capacitor motor, the capacitor is used for providing higher starting torque with lower starting current.

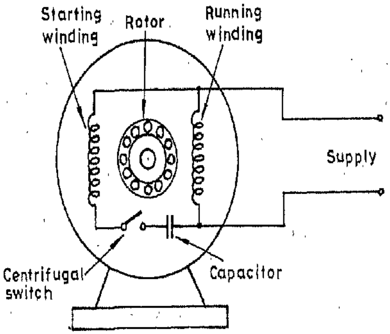


Fig. 1.1 Split phase capacitor motor

Three-phase motor consists of stator, rotor, and end plates. It is almost similar in construction to single phase motor. The stator has laminated core and accomodates winding in it. Core is fixed inside the stator frame. For small capacity motors, the rotor is of squirrel cage type and for large capacity motor it is wound rotor. Rotor core is pressed and mounted on shaft. The end plates are bolted to each side of stator frame, which accomodates bearing and shaft in it. Usually ball bearing is used on non-driving end and roller bearing is used on driving end.

Once the faults are detected, it is necessary to note down specific information concerning the old winding, so that no difficulty is encountered when the motor is repaired. The information is recorded before and during the process of dismantling.

For single-phase motors the details to be noted are: name plate details, number of poles, pitch of the coil, number of turns in each coil, size of the wire on both the windings, such as starting and running winding, the position of windings related to each other, type of winding such as hand winding or skein winding and class of insulation.

For three-phase motors the details to be noted are : name plate details, number of slots, number of coils, type of connections, number of turns per coil, size of coil, pitch of the coil, class of insulation and size of winding wire.

For dismantling the motor a definite procedure is followed so that the motor can be reassembled easily. Note down the details of winding during stripping out the windings from slots. However, care should be taken to save at least one complete coil, so as to record the dimension.

Tools, Equipment and Materials

(i) Centre, Punch or Hacksaw blade
(ii) Hammer
(iii) Cold chisel 10 cm
(iv) Wooden Mallet
(v) Bearing Puller
(vi) Screw driver, 20 cm
(vii) DE spanner set 6mm to 25 mm
(viii) G I Tray
(ix) Pliers 10 cm
(x) Burnt single phase or three phase motor
(xi) Pulley Puller.

Procedure

A. *Single-phase motor*

(i) Note down name plate details of the motor.
(ii) Mark on both end covers and body of the motor with the help of the centre punch or hacksaw blade.
(iii) Remove pulley key and pulley with the help of pulley puller (if motor is mounted with pulley).

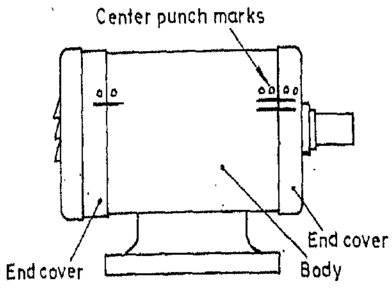


Fig. 1.2 Marking on body and end covers of a motor for dismantling

(iv) Disconnect capacitor and centrifugal switch connection from motor terminals.
(v) Remove the fan cover.
(vi) Remove external fan.
(vii) Unscrew the screws of bearing cap and remove bearing cap.
(viii) Remove end cover bolts, which are fastened with body of the motor.
(ix) Tap the end covers with the help of wooden mallet and remove them out.
(x) Take out rotor, carefully from stator.
(xi) Remove bearings if necessary with the help of bearing puller.
(xii) Note down starting winding details such as coil pitch, number of coils in each group and number of groups.
(xiii) Once the coils are stripped out, note down size of the coils, number of turns in each coil, size of wire and type of winding.
(xiv) Note down running winding details such as number of coil groups, number of coils in each group, number of turns in each coil, coil pitch, gauge of the wire, type of winding and type of insultation.

B. *For three-phase motor*

(i) Note down the name plate details of the motor.
(ii) Mark on both end covers and body of the motor with the help of centre punch or hacksaw blade.
(iii) Remove pully key and pulley with the help of pulley puller. (If pulley is mounted on the shaft.)
(iv) Remove the fan cover.
(v) Remove external fan.
(vi) Unscrew the bearing cap screws on both ends and remove cap.
(vii) Remove end cover bolts which are fastened with body of the motor.
(viii) Tap the end covers with the help of wooden mallet and remove them out.
(ix) Take out rotor carefully from stator.
(x) Remove bearing with the help of bearing puller if necessary.
(xi) Note down winding details such as number of slots, number of coils, number of coils in each set of group and coil pitch.
(xii) Note down motor operation connection wether it is star or delta connected.
(xiii) After stripping out motor winding, note down shape, size of the coil, number of turns in each coil, gauge

of the wire and type of insultation paper used in the process of winding.

Tabular Record of Observations

Table No. 1

Data sheet for single-phase motor

Name plate details

Make ——

Phase ——

Volts ——

Cycles ——

Temp. ——

Sr. No. ——

HP/KW ——

Amperes ——

Type ——

Frame ——

Model ——

Insulation ——

Winding Details

Winding	*No. of coil groups*	*No. of coils in each group*	*Pitch of the coil*	*Turns in each coil*	*Wire gauge no.*
Starting Winding			Outer coil.... Middle coil.... Inner coil....		
Running Winding			Outer coil.... Middle coil.... Inner coil....		

Rotation Direction

Table No. 2

Tabular records for three-phase motor

Name plate details

Make ——

Serial No. ——

Type ——

Frame ——

Style ——

Rating ——

RPON ——

Volts ——

Phase ——

Cycles ——

Amps ——

Connection ——

Insulation class ——

Winding Details

No. of slots ——

No. of coil groups ——

No. of coils in each groups ——

No. of turns in each coil ——

No. of poles ——

Gauge of wire ——

Type of connection ——

Insulation material used ——

Precautions

(i) Care should be taken to cut off or disconnect power supply before dismantling the motor.

(ii) Do not use chisel, hammer or screw driver for removing motor end covers.

(iii) Put the bearing puller arms on inner race of bearing and then pull the bearing carefully.

(iv) Draw rotor carefully for protecting stator windings.

Questions

(i) Explain the procedure for dismantling of single-phase (split-phase) motor.

(ii) Explain the procedure for dismantling three-phase motor.

(iii) Mention detailed data to be noted before dismantling and during the process of dismantling.

ACTIVITY NO. 2

Removal of Burnt Winding Coils from Stator of A.C. Motor

Specific Objective

(i) To develop skill for removal of burnt coils from stator of A.C. Motor.

Related Information

It is an important and skilled job to remove old burnt windings from stator for rewinding.

Before coils are removed from slots, winding details such as number of coils, coil group, number of coils in each group and coil pitch are noted for three-phase motor. Similarly, details of starting and running winding are noted down in case of single-phase motor. Apart from this, number of turns in each coil, size of wire and type of insulation used are also noted down during the process of removal of windings.

Motors of high capacity have open slots in the stator. It is necessary to remove wedges and pull out the coil from slots. Motors of small and medium capacity have semi-closed slots and removing of coils from these slots is difficult. When the winding are hard baked, cut the coil on one side of stator and pull the wires through the other side. This is illustrated in Fig 2.1.

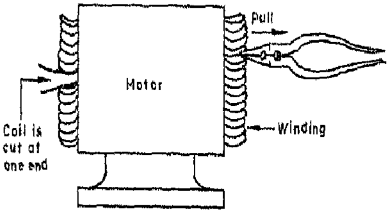


Fig. 2.1 Process for Removing Burnt Coil from Stator Winding

The simplest method of removing coil is to remove wedge by cutting with hacksaw blade or tapping out the wedge with the help of chisel and hammer. Passing high current through winding or heating stator winding in oven will soften the insulation and this will help easy removal of windings. At least one coil should be saved during the process of removal of winding so as to note dimension for making a former.

After the winding is removed slots must be cleaned thoroughly by removing burnt insulation. If the stator is sticky clean with kerosene.

Tools, Equipment and Materials

(i) Hacksaw blade
(ii) Hammer
(iii) Pliers
(iv) Knife
(v) Kerosene
(vi) Burnt out motor
(vii) Mallet

Procedure

(i) Note down the winding details such as number of slots, number of coils, coil pitch, number of coils in each group
(ii) Keep the stator in a heating oven for some time to soften the varnish insulation
(iii) Remove the stator from oven
(iv) Cut the wedge with the help of hacksaw blade and pull them out
(v) Cut the coils, on one side of stator with the help of hacksaw blade and pull out the wires from the other side
(vi) Save at least one complete coil so as to note dimensions for making new coil during rewinding process
(vii) Remove the slot insulation
(viii) Clean the stator and slots with kerosene to remove sticky varnish
(ix) If stamping of stator are bent at edges tap them gently with the help of wooden mallet and consolidate.

Tabular Record of Observations

Winding details before removal of coil

(i) No. of phases ________
(ii) No. of total slots ________
(iii) No. of coils ________
(iv) No. of poles ________
(v) No. of groups ________
(vi) Coil pitch ________
(vii) Details of starting ________
winding/running ________
winding. ________

Winding details during removal process

(i) Type of wedges used ________
(ii) Gauge of wire ________
(iii) No. of turns of each coil ________
(iv) Details of running/starting windings __
(v) Type of separator and insulation ____
(vi) Type of insulating varnish ________
(vii) Type of connections ________
(viii) Whether complete coil is saved from old windings ________
(x) Weight of one coil ________

Precautions

(i) Do not damage stator core while removing coils
(ii) Do not overheat stator core

(iii) Use low voltage for circulating current through burnt out coil for softening varnish

(iv) Do not forget to remove rotor, during circulating current through winding

(v) Do not forget to note down winding details before and during coil removal process

(vi) Save at least one complete coil for noting coil dimensions.

Questions

(i) What are the winding details to be noted down before coils are removed from stator ?

(ii) What are the winding details to be noted down during the process of removing old coils from stator ?

(iii) Why at least one coil should be saved from winding, during coil removal process from stator ?

ACTIVITY NO. 3

Preparation of Coils of A.C. Motor

Specific Objectives

(i) To make former for making coils

(ii) To wind single-phase stator coils of A.C. motor

(iii) To wind three-phase stator coils of A.C. motor.

Related Information

Former Making

In case of single-phase motor, stator coils are of different sizes as they are wound for concentric winding. For making these coils, former of different sizes are prepared. Coilformers are assembled as shown in Fig. 3.1 and mounted on a spindle of winding machine.

In case of three-phase motor, stator coils are of same size. Hence one former can serve the purpose of coil making for entire stator coils.

To obtain coil size, it is always suggested to save one complete coil from old winding during the process of stripping the coils or the size of coil can be determined by taking actual measurement by placing one single conductor in slots considering the coil pitch. Once the size of coil is confirmed the sample coil is kept on wooden board and marked on it. According to the size the wooden board is cut. This is illustrated in Fig. 3.2. The former is mounted on winding machine for making coil.

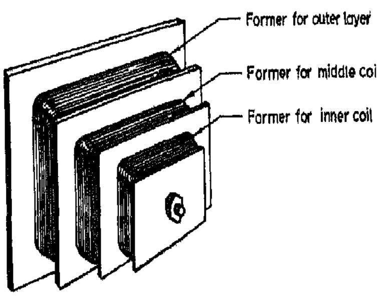


Fig. 3.1 Former for making split-phase motor stator coil

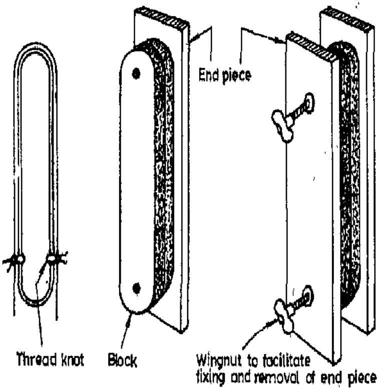


Fig. 3.2 Former for making three-phase motor coils

Even simple former can be made by using board and nails as shown in Fig. 3.3. Six nails are fixed as per size of the coil on a piece of board and coils are wound on it. If the nails are bent as shown in the figure, wound coil can be removed easily. The former can be held in hand or can be mounted on the spindle of winding machine for winding.

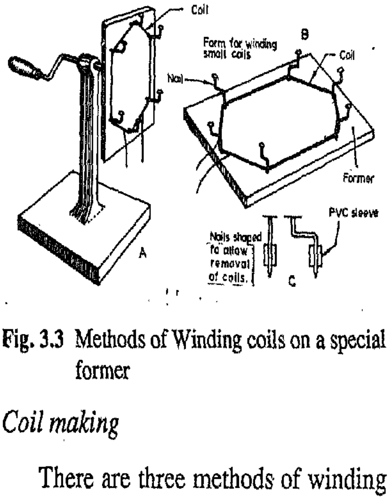

Coil
B
Form for winding small coils
Coil
Nail
Former
PVC sleeve
A
Nails shaped to allow removal of coils.
C

Fig. 3.3 Methods of Winding coils on a special former

Coil making

There are three methods of winding split-phase motors such as hand winding, former winding and skein winding. However, former winding is more convenient.

In hand winding, the wire is placed in the slots and wound turn by turn, starting with inner coil. In former winding, coils are prepared on former and later placed in the stator slots. Skein winding method is used mainly for starting winding of single-phase motor. The coil is made large enough to be wound into all the slots necessary to complete the individual section of a pole. The advantage of this method lies in the fact that many conductors can be placed in the slot at one time.

Coils of small motors are wound into rectangular form and then shaped by pulling the two sides. Coils are wound on former whose dimensions are taken from the old coil. The most common method for making coil is former type of winding. For making coils place two side pieces on former block with the help of clamps and mount the same on winding machine. Fix one end of proposed coil end on side piece of former. Rotate the former and go on winding the coil turn by turn, such that, it is wound in layer form. Once the coil is completed, it is tied in several places to hold the turns together. After removing the coil from the former, it is shaped by hand. If necessary it is taped as per original winding.

In large size three phase motor, the slots are generally open and the coils are usually completely taped. In medium size motors the slots are generally semi-closed and the coils of such motors are partially taped, that is on the portion where it is extended outside the slots. On fractional horse power motors, coils are not taped because of the size.

Tools, Equipment and Materials

(i) Scale
(ii) Tennon Saw
(iii) Firmer chisel

(iv) Wood rasp file
(v) Drill machine
(vi) Wire nails
(vii) Cotton tape 6 mm width
(ix) Enamelled copper wire
(x) Coil winding machine
(xi) Wooden board 0.5 meter × 0.5 meter × 15 mm
(x) Wooden batten for block making.

Procedure

Former Making

(i) Place the old coil or sample coil made by taking actual size of coil considering coil pitch on wooden board or batten
(ii) Mark the coil size with the help of pencil
(iii) Cut the wooden batten according to size and file the edges
(iv) If it is for split-phase motor, assemble all the blocks with nut and bolt by drilling hole at centre of each block
(v) Make two side pieces as per requirement to hold the coil on former as per Fig. 3.2 for making three-phase motor coils
(vi) Assemble the entire assembly on winding machine spindle.

Coil Making

(i) Collect the required gauge of wire for making coils.
(ii) Fix the wire spool on stand as illustrated in Fig. 3.4 for making coils

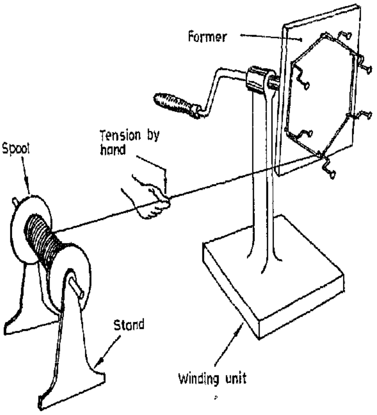


Fig. 3.4 Arrangement of former and wire spool during coil winding

(iii) Set the counter to zero
(iv) Fix one end of wire on one side of former and mark it as starting end
(v) Rotate the former by hand until one complete turn of wire is on the former
(vi) Rotate the former slowly at initial stage as there are chances of wire to pile up
(vii) Hold the wire by hand to avoid piling and to guide wire to form layer on former
(viii) Stop rotating the former once the number of turns are completed in the coil
(ix) Cut the finishing end of wire to separate it from spool and mark it as finishing end.

(x) Remove the wound coil from former and tie with thread to hold all turns together

(xi) Shape the coil by hand pulling its two ends

(xii) Tape the coil using cotton tape if required

(xiii) Repeat the process to make other remained coils.

Tabular Record of Observations

(i) Size of the old coil :

(ii) Size of the wire used :

(iii) No. of the coils to be prepared for single-phase motor or three-phase motor :

(iv) Number of turns used in each coil :

(A) Single-phase motor starting winding/ running winding.

(a) Outer coil—

(b) Middle coil—

(c) Inner coil—

(B) Three-phase motor coils

Precautions

(i) Check carefully the gauge of wire

(ii) Avoid scratches on wire during coil winding

(iii) Do not wind coil by over strain as wire may rapture

(iv) Do not forget to make the ends

(v) Ensure layer formation during coil winding.

Questions

(i) Why is it necessary to save one complete coil during the process of stripping of winding ?

(ii) What are the different methods for coil making for split-phase motors ?

ACTIVITY NO. 4

Preparation of Slots and Slot Insulation of A.C. Motor

Specific Objectives

(i) To know dielectic strength of insulating material

(ii) To understand the necessity of insulating the slots

(iii) To the familiar with cleaning agents used for cleaning the stator

(iv) To develop skill in insulating slots.

Related Information

After removing the winding, the slot should be cleaned. If the insulation is charred, its removal is comparatively simple, because it will fall out as the wires are removed. But if the insulation sticks in the slots, a knife or sharp edge instrument may be used to loosen it. In case, stator is greasy it should be washed with cleansing liquid (Preferably with non inflammable cleaning agent)

For re-insulating the slots, it is better to use the same type and size of insulation as was employed in the original winding. The insulation is so cut that it is about 5mm longer than the slot and is shaped to fit in the slots.

The following points should be borne in mind for selection of insulation:

(a) Working temperature of the motor

(b) Use of Motor in Chemical Industry or Pump House.

Different types of insulating materials are used for insulating slots. Dielectic strength of the insulating material depends upon its thickness. Technical and Commercial names of the insulating materials are given below:

Technical Name	*Commercial Name*
(a) Press paper	Leatheroid paper Elephentide paper
(b) Cambric cloth	Empire cloth
(c) Polyester paper	Melinex/Mylar paper
(d) Press paper with Polyester film	Symax

Mostly commercial names are used for identification of insulation materials.

Tools, Equipments and Materials

A : Tools

(i)	Insulated long nose plier	15 cms—one
(ii)	Insulated screw driver	15 cms—one
(iii)	Knife	15 cms—one
(iv)	Scriber	25 cms—one
(v)	Wood butten	25 cms × 10 cms—two
(vi)	Mallet	200 gms—one
(vii)	Hacksaw Blade	300 mm—one
(viii)	Scissors	200 mm—one pair
(ix)	Bamboo strips	As per requirement for pressing and placing the insulating paper in the slot.
(x)	Steel scale	300 mm—one
(xi)	Air blower	200 watts 220 Volts—1 no.

B : Materials

(i) Insulating paper employed in the original winding (Leatheroid paper 5 mil, 1 meter for motor less than 2 HP)
(Leatheroid paper 10 mil, 2 meter for motor more than 2 HP and less than 5 HP)

(ii) Cleansing liquid 1/2 ltr. C.T.C. (Non-inflammable).

Procedure

(i) Trim the stampings with the help of mallet or wood batten.

(ii) Blow out whatever dirt grit or foreign material is lodged in the slots of the stator by air flower.

(iii) Remove the insulation with the help of scriber from the slots.

(iv) Use blower to remove dirt.

(v) In case, stator is greasy wash it with cleansing liquid.

(vi) Cut the insulating paper to size.

(vii) Fold the insulation paper to suit the slot.

(viii) Place and shape the paper to fit the inside walls of the slots with the help of bamboo strips.

Tabular Record of Observation

(*a*) *Motor Name Plate*

(i) Serial No.:
(ii) HP/Wattage:
(iii) Volt:
(iv) Ampere:
(v) Class of insulation:
(vi) Year of manufacture:
(vii) Temperature:
(viii) Rating:
(ix) R.P.M.:
(x) No. of Poles:
(xi) Frequency:

(b) Name of Manufacturer:
(c) Types of Insulation:
(d) Thickness of Insulation:
(e) Quantity of Insulation:

Precautions

(i) Do not hammer the stampings

(ii) Don't leave any dirt, grit and foreign material inside the slots

(iii) Place insulation inside the slots firmly and gently

(iv) Do not use metallic piece while placing the insulation in the slot

(v) Wash the stator only with non-inflammable cleansing liquid.

Questions

(i) What are the different types of insulating paper?

(ii) What will be the effect of putting excess insulation in the slots?

(iii) What will happen if slot insulation is of the same length as that of the slot?

ACTIVITY NO. 5

Inserting Coils in Slots of Stator of A.C. Motor

Specific Objectives

(i) To be familiar with different types of slots
(ii) To know the use of standard wire gauge and micrometer
(iii) To familiarise with the insulation of winding wire
(iv) To develop skill for inserting coils in slots.

Related Information

In A.C. Motors above 15 H.P., the slots are generally open type and below 15 H.P., the slots are generally semi-closed. It is difficult to insert coils in semi-closed slots compared to open type slots. The turns of coil are inserted one by one into the slot. The ends are tagged after each coil is placed in the slot. The coils are cased into the slot with the help of wedge made of bamboo or fibre.

Tools, Equipment and Materials

Tools :

(i) Insulated long nose pliers 150 mm — one
(ii) Insulated combination pliers 200 mm — one
(iii) Insulated screw driver 4 mm × 150 mm — one
(iv) Insulated screw driver 6 mm × 250 mm — one
(v) Scissors 250 mm — one
(vi) Knife 200 mm — one
(vii) Wooden Batten 25 mm × 300 mm — one
(viii) Wooden Mallet 500 gm — one
(ix) Fibre wedge — two

Equipment :

(i) Insulation Tester (Megger) 500 volts — one
(ii) Series Test lamp 220 v, 60 w — one

Materials :

(i) Stator
(ii) Insulation paper 5 mm — 1 meter
(iii) Binding thread 100 gms
(iv) Cotton Tape 20 mm — 2 bundles
(v) Bamboo/fibre
(vi) Empire Sleeves.

Procedure

(i) Check that the slot of the stator are fitted with proper insulation

(ii) Spread or fan out the turns on one side of the coil

(iii) Hold the coil at such an angle as to facilitate insertion of all the turns of the coil into the slot

(iv) Place turns of the coil one by one and set the turns by moving a fibre piece in the slots

(v) Keep the other side of the same coil free

(vi) Place one side of the second coil in proper slot as per winding data

(vii) Repeat step (vi) as per the coil pitch of a three-phase motor. In connection with following two cases:

  (a) If coil pitch is 1-6, keep second side of a first three coils free.

  (b) If coil pitch is 1-4, keep second side of first two coils free.

(viii) Insert both sides of remaining coils in the slots as per the winding diagram

(ix) Insert paper insulation in between the overhang portion of two coils

(x) Insert the wedges into the slots over the coils so that conductors are firmly held

(xi) Tape the overhung portion of the coil

(xii) Put sleeves on the leads of wire

(xiii) Make end connections as per winding diagram

(xiv) Solder the joints

(xv) Take out the connection lead on to the terminal block.

Tabular Record of Observations

Details of motor	*Winding Data*
Make ____	Number of slots ____
S.No. ____	Number of coils ____
Model ____	Number of Turns ____
H.P./KW ____	Per coil ____
No. of phases ____	Size of coil ____
Volts ____	Coil pitch ____
Type of connection ____	No. of poles ____
Frequency ____	Size of conductor ____
RPM ____	Type of Insulation –
Rating ____	Type of winding ____
	Connection ____
	Size of conductor of main leads ____
	Date of receipt ____
	Date of rewinding ____
	Date of delivery ____
	Test Chart :
	Insulation Test ____
	Earth Test ____
	Continuity Test ____

Precautions

(i) Do not use hammer or any other metallic bars on the conductor

(ii) Make sure that each turn of the coil is placed inside the insulation of the slot

(iii) Coil should not be left loose in the slot

(iv) The coil side must not press against the iron cores at the corner of the slot

(v) Shape overhang coils in such a way so that it may not touch the rotor

(vi) Always place insulation between two coils at the overhangs.

Question

(i) How does cross sectional area of a conductor affect the resistance ?

Making Stator Winding Connections of A.C. Motor

Specific Objectives

(i) To prepare winding diagram.

(ii) To connect the coils of all phases as per the developed winding diagram and bring out the leads to the terminal block

(iii) To identify the leads and label them.

Related Information

A.C. winding consists of coils housed in slots. In single layer, number of coils is one half the number of slots. In double layer, number of coils is equal to the number of slots. The number of coils per phase is equal to total number of coils divided by number of phases.

The number of coils per pole per phase is equal to the number of coils per pole divided by the number of phases. e.g. consider 36 slot, double layer, lap winding with 4 poles, 3 phase.

No. of coils = 36.

No. of coils per phase = $\frac{36}{3} = 12$

.No. of coils per phase per pole = $\frac{12}{4} = 3$

No. of coils per pole = No. of phases × coils per pole per phase.

$$= 3 \times 3 = 9$$

$$\text{Slot angle} = \frac{\text{Pole pitch}}{\text{Number of slots per pole}}$$

$$= \frac{180^\circ}{9} = 20^\circ$$

Coil span is equal to 180° for full pitch and less than 180° for short pitch.

In this example, a full pitch coil spans slots i.e. 1 to 10, a short pitch coil chorded by 1 slot spans 8 slots i.e. 1 to 9.

Fig 6.1 shows coil grouped under each pole.

Fig. 6.2 shows the shape of coil.

Fig. 6.3 shows a coil group under a pole

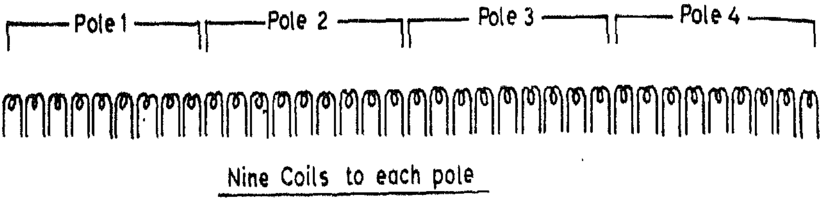


Fig. 6.1 A 36- coil, three-phase motor with coils divided into poles

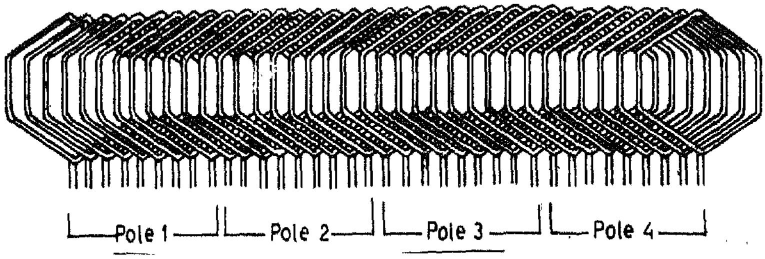


Fig. 6.2 The shape of coils

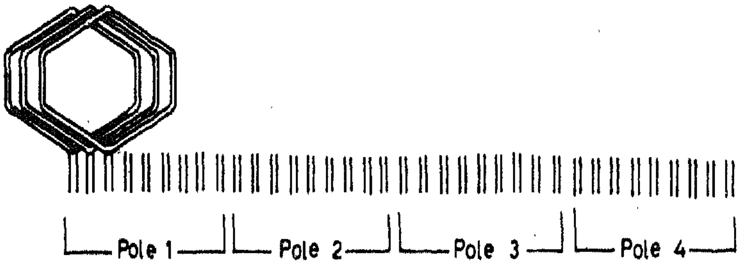


Fig. 6.3 Coils in a three-phase four-pole motor

The number of coil under one pole belonging to one phase, connected in series is called a pole phase group. Connection of pole coils are shown in Figs. 6.4, 6.5. They are always in series. All phase groups under all poles of any one phase is connected in series so that the emfs are additive. This constitutes one phase winding, the leads are labelled u_1 and u_2. Similarly the coils of the other phase are grouped and connected. The leads are brought out and labelled as V_1, V_2 and W_1, W_2. The polarity N and S is achieved by changing the direction of flow of current in the successive coils groups i.e. the end connections are reversed for every coil group. The completed winding has to be connected either in star or in Delta to receive 3-phase supply. If all the beginnings or ends are joined together, that connection is called star connection (Wye). If the end of one phase is connected to the beginning of the other, that connection is called delta connection (Mesh). For single phase motor, the windings consist of (a) Starting winding and (b) Running winding. The windings are usually chain windings either half coil or whole coil usually whole coil.

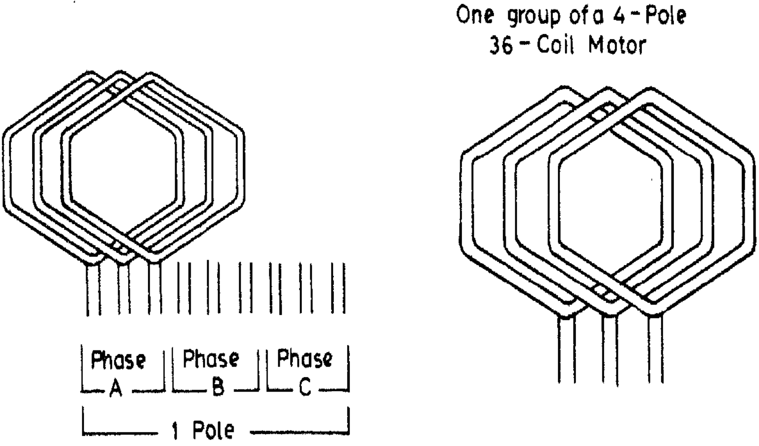


Fig. 6.4 Three groups in one pole having three coils in one group

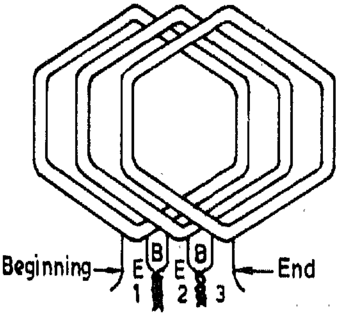


Fig. 6.5 End connections of coils

The coils under one pole are grouped and connected in series forming one coil group. Such groups are connected in series to form the desired poles. The same pattern repeats for the other winding (Starting winding). The two windings are spaced 90° apart in space. The gauge of conductor is higher for starting winding (Auxiliary winding) and gauge is smaller for Running winding (Main winding).

Tools, Equipment and Materials

(i) Insulated combination pliers- 20 cms

(ii) Insulated long Nose pliers - 15 cms
(iii) Insulated screw driver - 20 cms, 15 cms
(iv) Knife
(v) Wire cutter
(vi) Scissors
(vii) Soldering iron - 65 watt
(viii) Series test lamp
(ix) Wooden mallet
(x) Wooden batten
(xi) Cotton tape - 20 mm
(xii) Binding thread
(xiii) Empire sleeve
(xiv) Soldering flux
(xv) Resin core solder of 60:40
(xvi) Cable for leads.

Procedure

(i) Form pole phase groups say (3 Coils)
(ii) Connect them in series (4 group)
(iii) Connect pole phase groups of any phase in series (12 coils)
(iv) Repeat the same for other phases
(v) Insert separator between phase groups at the overhangs
(vi) Tape of coils at the overhangs
(vii) Shape the overhangs
(viii) Route the jumpers, remove insulation by sandpaper, sleeve the leads, join them and solder the joints
(ix) Solder cable to the beginning and end of each phase and connect the cable lead to the terminal block
(x) Connect the coil groups of the winding under every pole in series (say Running winding)
(xi) Repeat the same procedure for starting winding
(xii) Solder all joints, tape the joints, position the overhangs and shape them
(xiii) Bring out the leads to the terminal block.

Tabular Record of Observations

Coils	*Coil per pole*	*Coils per pole per phase*	*Coils per phase*

Precautions

(i) Use sandpaper for removing enamel insulation and not knife or emery paper
(ii) Tag the leads properly at the time of end connections.

Questions

(i) Calculate the coil per phase, coils per phase per pole for 24-slot, 3-phase, 4-pole double layer winding
(ii) Calculate the slot angle for question (i)
(iii) If the coil is short pitched by 2 slots, calculate the coil pitch.

ACTIVITY NO. 7

Identification of Terminals of Stator of A.C. Motor

Specific Objectives

(i) To recognise the terminals of the phase winding
(ii) To mark the terminals of phase winding
(iii) To insert tags in the sections of windings for identification.

Related Information

It is necessary that the phase windings of the stator must be connected with correct polarities. This results in rotation of magnetic field when 3 windings are supplied with 3-phase A.C. supply with incorrect polarities the absence of rotating magnetic field does not result the rotation of the motor.

When the winding is supplied with a.c. voltage, the emf is induced in the neighbourhood winding due to the transformer principle (electro-magnetic induction).

Three windings terminals are identified as u_1 - u_2; V_1 - V_2 and W_1 - W_2. The star connected motor is formed by connecting strips between u_1 and v_1, as well as between v_1 and w_1 to form star point. In Delta connected motors, the connections between u_1 and w_2; v_1 and u_2 and w_1 and v_2 are made by 3 strips connected to 3-phase supply terminals.

Tools, Equipment and Materials

(i) Portable A.C. voltmeter (0-600 v) or multimeter
(ii) One bulb of 40 watt, 230 volts
(iii) Switch
(iv) Connecting leads
(v) Electrician's Too kit
(vi) tags

Procedure

(i) Skin the end of all the phase-windings of rewound stator and prepare the tags to be used to insert in the ends of the windings
(ii) Choose one of the phase-windings as a reference say U-winding and name both the ends by inserting the tags as u_1 and u_2. The terminal

u_1 indicates the start of the u winding and u_2 indicates the end of the u winding

(iii) Make the connections as shown in the Figure 7.1, by connecting the U-phase winding in series with a switch and a given bulb across the 230 volts AC, single phase supply

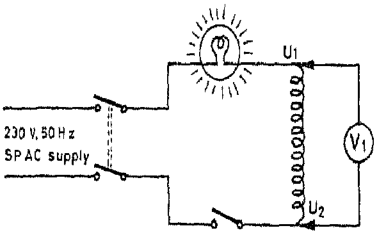


Fig. 7.1 Continuity test

(iv) Observe whether the bulb glows. If it glows, the winding has continuity. Then note down the voltage across the terminals of the windings u_1 and u_2 by voltmeter. Let this reading be V_1

(iv) Switch off the circuit

(v) From the remaining two phases of rewound stator, select one winding as V winding. Connect its one terminal to the u_2 terminals of u-phase as shown in the Figure 7.2 with other terminal of V winding left open

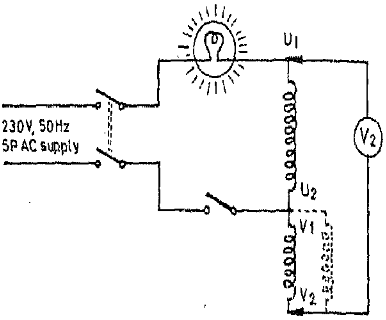


Fig. 7.2 Polarity test

(vi) Switch on the supply and note down the reading on voltmeter (V_2) across both the windings u and v winding. The voltage induced in the v-winding due to transformer action is included in this reading

(vii) Switch off the circuit

(viii) Make tabular record of observation and compare the magnitudes of voltage v_1 and v_2 to identify the terminals of V phase

(ix) If the reading on voltmeter V_1 is greater than the reading on voltmeter V_2, mark the polarities as follows. *'End'* of the first (reference) phase is connected with the 'START' i.e. beginning of the next phase winding or (begining with end). This means for $V_1 > V_2$; u_2 terminal is connected with V_1 terminal of V-phase and the remaining unconnected terminal of V-phase is V_2. Insert the relevant tags at the ends of that windings

(x) If the reading on voltmeter V_1 is less than the reading on voltmeter V_2, mark the polarities as follows: 'END' of the first (reference) phase winding is connected to the 'END' (or beginning with begining). This means for $V_1 < V_2$; u_2 terminals is connected with V_2 terminals of V-phase and the remaining unconnected terminal of V-phase in V

(xi) Repeat the procedure steps (V) to (X) with the remaining last phase winding (w) of the rewound stator to identify terminals w_1 and w_2 by inserting relevant tags.

Precaution

(i) Handle stator carefully.

Questions

(i) What is the necessity of identification of terminals ?

(ii) What will happen if the terminals are not identified ?

(iii) Why the voltage across two windings in polarity testing is higher or lower than the voltage across reference winding ?

Tabular Record of Observation:

Sr. No.	*Voltage across reference u-winding (V_1) Volts*	*Voltage across two winding (V_2) Volts*	*Comparison* $V_1 > V_2$
1			Yes i.e. End to Start No. i.e. Start to Start
2			Yes i.e. End to Start No. i.e. Start to Start

ACTIVITY NO. 8

Testing Stator Winding of A.C. Motor

Specific Objectives

(i) To know correct testing procedures
(ii) To arrange and conduct the tests
(iii) To develop safety consciousness
(iv) To develop skills for testing stator winding.

Related Information

The rewound stator of A.C. motor must be tested before assembly and final testing to ensure that all the faults and error at the stage of rewinding are detected and rectified. The stator is tested for

(a) Continuity
(b) Insulation resistance
(c) Correct magnetic polarity
(d) Balanced electrical windings
(e) High voltage flash testing
(f) Growler test for stator

Continuity test is conducted by a test lamp. Each phase winding is tested for continuity. 230 V A.C. is given to a phase winding through a 40 W series lamp. If the lamp glows, there is continuity, otherwise there is an open circuit.

Insulation Resistance Test is conducted by a megger/Ohm meter. The megger is connected between each phase and frame and rotated at constant speed. It should not show continuity and should read a minimum of 10 Megohms at room temperature. The test is repeated for other phases. The Megger is also connected across any two phases for insulation resistance measurement. It should read a minimum of 10 Megohms at room temperature.

Magnetic Polarity Test is conducted by the use of a low voltage D.C. supply and a magnetic compass. The magnetic compass should show as many poles as the winding is intended to develop. A low voltage D.C. of 6 to 12 V is connected to any one phase. The magnetic compass is held inside the stator and the poles are identified. This is repeated for other two phases.

Balanced Electrical windings test is used to verify electrical balance. Resistance of each phase is measured using Multimeter. This test can also be conducted by applying 230 V 50 HZ supply through a lamp and an ammeter in series to any one phase winding. The same procedure is repeated for the other two phases. The ammeter readings should be the same in all the three cases.

High Voltage Flash testing is conducted to test dielectric strength of the insulation. A high voltage of 1.8 KV (1000V + twice the working voltage) is applied between two windings for one minute by a high voltage flash tester. If it withstands the voltage, the dielectric strength is good. The procedure is repeated for other two windings. This ensures that the insulation can withstand normal working voltage and also surge voltages.

Growler test is conducted to determine shorts in coils and to isolate and replace the shorted coil.

Tools, Equipment and Materials

(i) Test lamp 230V 40 watts
(ii) Multimeter
(iii) Ammeter (moving iron) 0-2A
(iv) Megger Ohmmeter 1000V
(v) Electricians tool kit
(vi) Magnetic compass
(vii) 12 V lead acid battery
(viii) HV Flash Tester
(ix) Growler

Procedure

Continuity Test

(i) Make connections as shown in Fig. 8.1

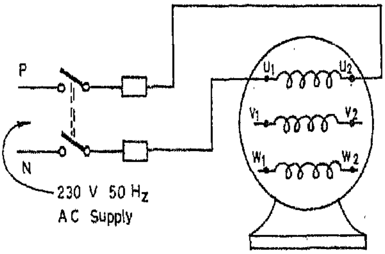


Fig. 8.1 Continuity test

(ii) Close the switch and verify whether the lamp glows bright or not
(iii) Observe and record glow of lamp.

Insulation Resistance Test

(i) Connected two terminals of the megger across any one winding the frame as shown in Fig. 8.2 (terminal L to U_1 and terminal E to frame)

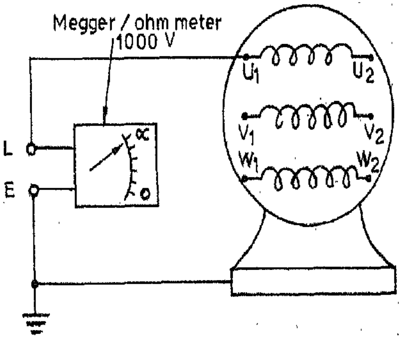


Fig. 8.2 Insulating resistence test

(ii) Rotate megger handle at constant speed
(iii) Note down the reading
(iv) If the value recorded is more than

10 Megohms, the insulation resistance is good

(v) Repeat the procedure for the other two windings.

Magnetic Polarity Test

(i) Connect a battery of 6V to any phase winding say U_1, U_2.

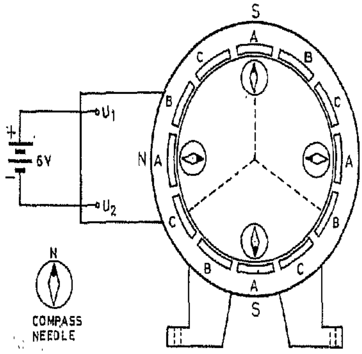


Fig. 8.3 Magnetic Polarity test

(ii) Hold a magnetic compass inside stator and move the compass round the stator.

(iii) Observe the needle movement and identify the poles.

(iv) Detect number of poles and record. Detect 4 poles.

(v) Repeat this procedure for other two phases.

Test for Electrical Winding

(i) Measure Resistance of any one phase winding say U_1 U_2 by megger/ Ohmmeter.

(ii) Record measured value.

(iii) Repeat the procedure for other two phase windings.

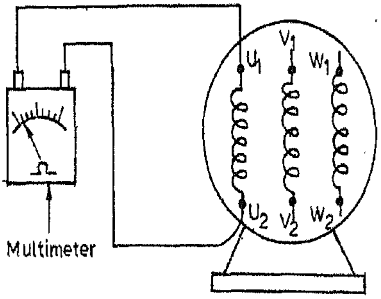


Fig. 8.4 Resistance test

UBC Test : Unbalance Current Test

(i) Connect a lamp of 40W or 60W and an ammeter 0-1 or 0-2A in series with any one-phase winding and connect it to supply

(ii) Close the switch and note down the reading

(iii) Repeat the procedure for the other two-phase windings.

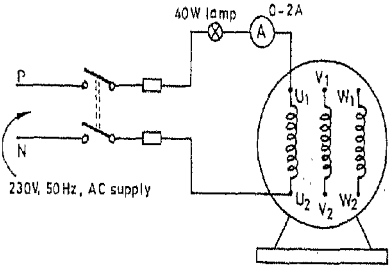


Fig. 8.5 U.B.C. test

NOTE : The three values must be equal to confirm balanced electrical circuit.

High Voltage Flash Test

(i) Connect Flash over tester to any one phase winding terminals U_1 and frame.

(ii) Apply the stipulated voltage (1000 V + 2 × 415V = 1830V) through selector switch for one minute duration.

(iii) It the insulation stands the voltage, the lamp will be 'ON'. If the insulation fails, the lamp will be OFF.

(vi) Repeat the same procedure for other two phases.

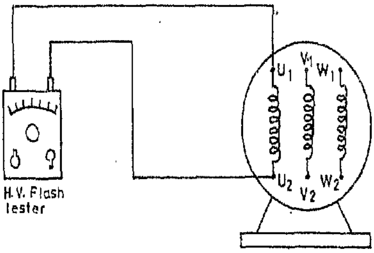


Fig. 8.6 H.B. Flash test

Growler Test

(i) Place the internal growler inside the stator periphery closing the magnetic path.

(ii) Connect a lamp of 60W in series.

(iii) Put on 230V A.C. supply switch.

(iv) Move the growler all round and hold a hacksaw blade piece one pole pitch apart and observe.

(v) Observe the blade the also feel the temperature of coils. If the coil is hot and/or the blade vibrates, there is an internal short in the coil.

(vi) If there is a short, replace the coil.

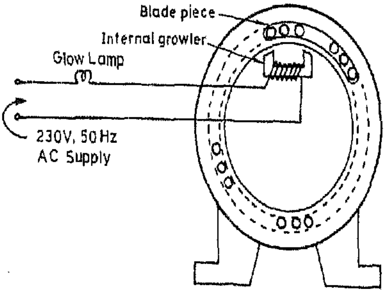


Fig. 8.7 Growler test

Tabular Record of Observations

Continuity Test		
Winding	*Condition of lamp*	*Remarks*
$U_1 U_2$	Glows	No O.C.
$V_1 V_2$	Glows	No O.C.
$W_1 W_2$	Glows	No O.C.

Insulation Resistance Test

Line to Ground Test		
Connection	*Megaohm*	*Remarks*
U_1 Phase and ground	5	OK
V_1 Phase and ground	5	OK
W_1 Phase and ground	5	OK
W_1 Phase and ground	5	OK

Phase to Phase Test		
U_1 and V_1	8	OK
V_1 and W_1	8	OK
W_1 and U_1	8	OK

Magnetic Polarity Test	
No. of poles as per name plate	*No. of poles identified by compass needle*
phase	
U	
V	
W	

Resistance Test		
Phase	*Reading in Ohms*	*Remarks*
U_1U_2	0.8 Ohms	
V_1V_2	0.8 Ohms	
W_1W_2	0.8 Ohms	

UBC Test		
Phase	*Ammeter Reading*	*Remarks*
U_1U_2	1.2 A	Same value
V_1V_2	1.2 A	Balance
W_1W_2	1.2 A	

High Voltage Flash Test	
Connection	*Lamp Indication*
U_1 to frame	ON
V_1 to frame	ON
W_1 to frame	ON

Growler Test				
Coils	1	2	3	4
Blade vibrates				
Blade does not vibrate				
Coils normal				
Coil hot				

Precautions

(i) Observe safety while conducting test

(ii) Megger handle must be rotated at constant speed

(iii) Do not remove glower when supply is connected to stator winding.

Questions

(i) What is the effect of moisture on the value of insulation resistance ?

(ii) What is the effect of application of H.V. for a larger period ?

(iii) Why the growler should not be lifted off the core ?

(iv) Can you check magnetic polarity with compass on A.C. supply ?

ACTIVITY NO. 9

Construction of Single Layer Lap Winding of Stator of A.C. Motor

Specific Activities

The student should be able to :

(i) Calculate the slots per pole and slots per pole per phase

(ii) Calculate slot angle

(iii) Draw the conductors in RYB colours

(iv) Form coils, draw and connections and bring it the leads of the terminal box.

Related Information

A three-phase winding is just three single phase windings 120° apart in space and the currents are 120° apart in time, so that the flux in the air gap is 120° apart in space and time.

A three-phase winding is thus a combination of conductors so connected that they are balanced magnetically, mechanically and electrically.

In lap winding, the coils overlap each other. Lap winding is mostly used in low voltage, high current machines. Due to its simple construction, it is exclusively used in most of the A.C. machines.

As an example, 4-poles, 24-slots, single layer, full pitched, lap winding, star connected motor is considered.

Tools, Equipment and Materials

(i) Drawing board and 'T' square

(ii) Instrument box.

(iii) Pencils (H, HB), Eraser

(iv) Red, Yellow, Blue coloured pens

(v) A2 size drawing sheet.

Procedure

(i) Calculate slots per pole

$$\text{Slots per pole} = \frac{\text{No. of slots}}{\text{No. of poles}} = \frac{24}{4} = 6$$

(ii) Calculate slots per pole per phase.

$$\text{Slots per pole per phase} = \frac{\text{Slots per pole}}{\text{No. of phases}} = \frac{6}{3} = 2$$

(iii) Calculate slot angle

$$\text{Slot angle} = \frac{180^\circ}{\text{No. of slots per pole}} = \frac{180^\circ}{6} = 30^\circ$$

(iv) Draw 24 slots, two conductors in red, two conductors in blue and two conductors in yellow, in sequence
(v) Draw poles, mark directions of poles
(vi) Draw coils and join coil groups
(vii) Repeat for remaining two phases
(viii) Make star connection
(ix) Label the terminals as u, u_2, v_1, $-v_2$ and w_1, $-w_2$.

Tabular Record

No. of slots	*No. of poles*	*Slots/Pole*	*Slot/pole/ phase*
24	4	6	2

Precautions

(i) Ensure RYB phase sequence
(ii) Note that the direction of emfs are not the same in all phases.

Questions

(i) If the motor is designed for star operation can it be connected in delta?
(ii) What is the disadvantage of full pitch winding?

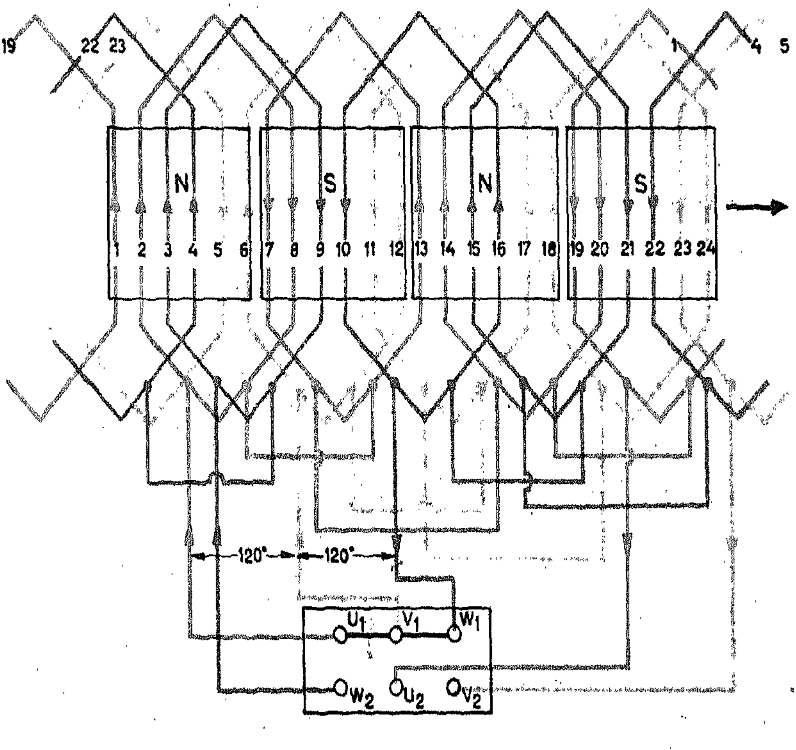


Fig. 9.1 Single layer lap winding of stator of a three-phase A.C. motor

ACTIVITY NO.10

Construction of Double Layer Lap Winding of Stator of A.C. Motor

Specific Objectives

The student should able to :

- (i) Calculate slots/pole, slots per pole per phase, slot angle
- (ii) Draw the conductors in proper sequence
- (iii) Connect all the coils and coil groups to get symmetrical three-phase winding.

Related Information

An A.C. winding is a group of insulated conductors connected to receive balanced three-phase supply. A double layer winding is very useful for making a short pitched winding chorded by desired number of slots to eliminate harmonics. A 4 pole, 24 slots, 48 conductors, double layer full pitched, lap winding, data connected motor is considered.

Equipment and Materials

- (i) Drawing board and 'T' square
- (ii) Instrument box
- (iii) H, HB and R, Y, B coloured pencils, eraser
- (iv) A2 size drawing sheet.

Procedure

- (i) Draw 24 slots for 48 conductors, one full line and other dotted line per slot
- (ii) Draw the lines in RBY sequence to get RYB phase sequence
- (iii) Draw poles
- (iv) Indicate direction of emf.
- (v) Draw coil groups
- (vi) Join all groups of one phase in series so that emfs are additive
- (vii) Bring the leads to the terminal block
- (viii) Draw delta connection in terminal block.

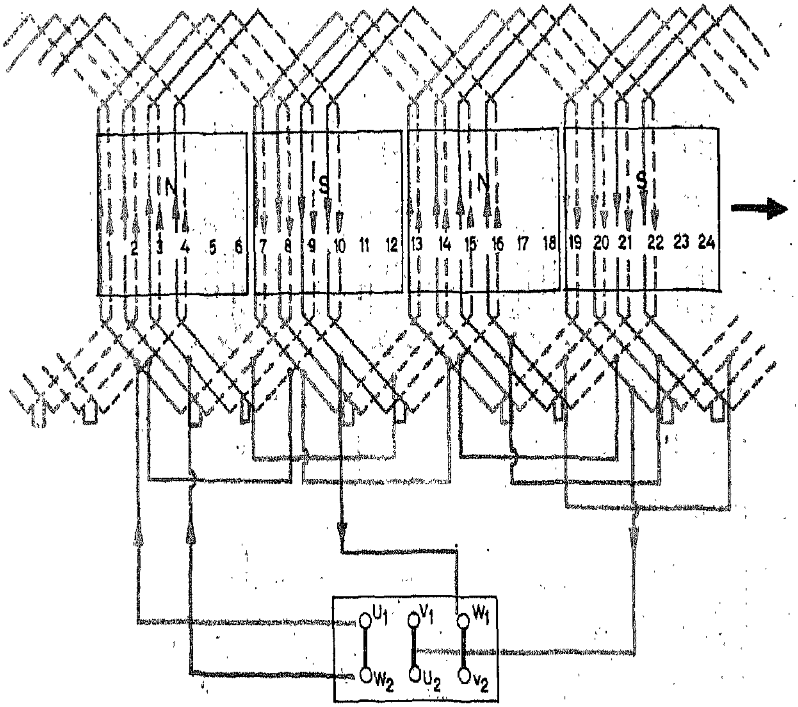


Fig. 10.1 Double layer lap winding of stator of a three-phase motor

Tabular Record of Observation

Number of slots	*Number of conductors*	*Number of poles*	*Slots per pole*	*Slots pole per phase*
24	48	4	6	2

Precaution

(i) Ensure proper Polarity for delta connection

Question

(i) What are the merits of double layer winding?

Construction of Single Layer Odd Coil Lap Winding of Stator of A.C. Motor

Specific Objectives

The student should be able to:

(i) Calculate slots per pole and slots per pole per phase
(ii) Calculate slot angle
(iii) Draw the conductors in RBY colours
(iv) From coils, draw end-connections and bring the leads of the terminal box.

Related Information

A three-phase winding is a set of three single phase windings, spaced 120° apart and the currents are 120° apart in time. Hence the flux in the air gap is spaced 120° apart in space and time resulting in a revolving magnetic field.

In case of single layer, odd coil, lap winging, the number of coil groups will not be equal for any given phase under all the poles. In this case, the coil groups are 2-1-2-1. A 4-pole, 36-slots, single layer, odd coil, lap winding delta connected motor is considered.

Tools, Equipment and Materials

(i) Drawing board and 'T' square
(ii) Instrument box
(iii) Pencils (H,HB), Eraser
(iv) A_2 size drawing sheet
(v) coloured pens (Red, Yellow, Blue)

Procedure

(i) Calculate slots per pole

$$\text{Slots per pole} = \frac{\text{No. of slots.}}{\text{No. of poles.}} = \frac{36}{4} = 9$$

(ii) Calculate slots per pole per phase

$$\text{Slots per pole per phase} = \frac{\text{Slots per pole}}{\text{No. of phases}} = \frac{9}{3} = 3$$

(iii) Calculate slot angle

$$\text{Slot angle} = \frac{180^\circ}{\text{slots per pole}} = \frac{180^\circ}{9} = 20^\circ$$

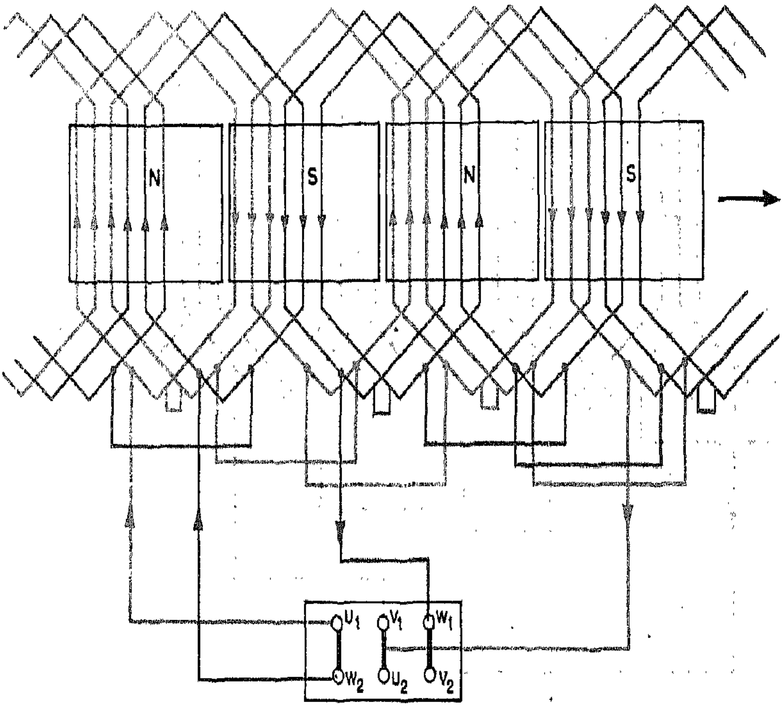


Fig. 11.1 Single layer add coil lap winding delta connected three-phase motor

Tabular Record of Observations

No. of Slots	*Slots/pole*	*Slots/pole/phase*
36	9	3

Precautions

(i) Draw conductors in red, blue, yellow sequence to get R-B-Y sequences.

(ii) Note that directions of currents in conductor with respect to poles is proper.

Questions

(i) Give applications of single layer odd coil, lap winding machines.

(ii) What are disadvantages of single layer, odd coil winding ?

(iii) What is the difference between star and delta connection ?

(iv) Why is delta connection preferred to star connection in A.C. motor ?

ACTIVITY NO. 12

Construction of Concentric Winding of Stator of A.C. Motor

Specific Objectives

(i) To understand concentric winding
(ii) To draw developed diagram of concentric winding.

Related Information

Chain winding is known as spiral or concentric winding. It may be two-tier or three-tier winding and half coil or whole coil. The coils are of different sizes. Concentric winding is used for single-phase motors, high voltage motors and generators. As coils do not touch or cross each other at overhangs, there is no chance of short circuit between coils.

Tools, Equipment and Materials

(i) Drawing board 'T' and set square
(ii) Instrument box and eraser
(iii) H, HB and RYB colour pencils
(iv) A_2 size drawing sheet.

Procedure

Consider a 3-phase, 36-slot, 4-pole, motor having two-tier concentric winding.

(1) Calculations :

$$\text{Slot per pole} = \frac{\text{Slots}}{\text{Pole}} = \frac{36}{4} = 9$$

Slots per pole per

$$\text{phase} = \frac{\text{Slots}}{\text{Poles} \times \text{phases}} = \frac{36}{4 \times 3} = \frac{36}{12} = 3$$

$$\text{Slot angle} = \frac{180^\circ}{\text{slots/pole}} = \frac{180^\circ}{9} = 20^\circ$$

(ii) Draw 36 conductors 3 red, 3 blue and 3 yellow in sequence
(iii) Draw poles and mark N-S-N-S
(iv) Mark direction of emfs
(v) Draw coils under each pole for Red phase
(vi) Join coils groups in series
(vii) Bring leads to terminal block
(viii) Repeat the procedure (v), (vi), (vii) for yellow phase and blue phase
(ix) Connect the terminals is star

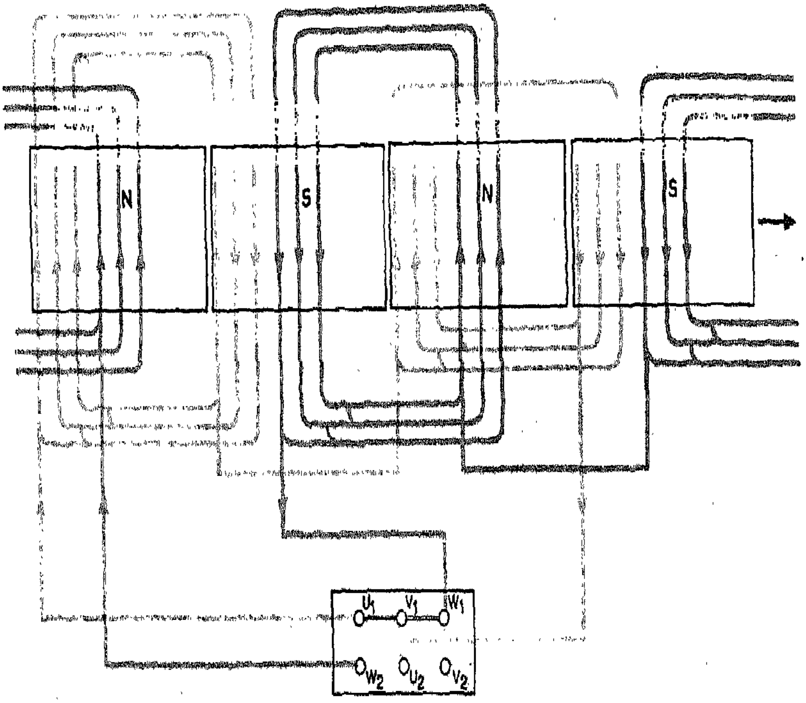


Fig. 12.1 Winding diagram of 36-slot, 4-pole 3-phase two-tier half coil star connected chain winding

Tabular Record of Observation

Number of slots	*Number of poles*	*Slot per pole*	*Slots per pole per phase*
36	4	9	3

Precaution

Ensure suitable gap between coils at the overhangs.

Questions

(i) Is the concentric winding full pitched or short pitched ?

(ii) Why concentric winding for high voltage motors ?

ACTIVITY NO. 13

Construction of Stator Winding of Dual Speed A.C. Motor

Specific Objectives

The student should be able to :

(i) Calculate number of coils

(ii) Calculate number of coils per phase

(iii) Draw the winding diagram forming coil groups and join coil groups as per winding diagram.

Related Information

The speed of three phase motors depends on number of poles and frequency of current. If the frequency remains the same, then to obtain different speeds in a three phase motor, number of poles must be changed. This alteration can be effected by changing the connection between groups. The two speed or dual speed, three phase motor can be connected to have constant horsepower at both speed, to have constant torque at both speed or to have variable torque at both speeds. For constant torque, the motor is connected in two parallel star for high speed and in series delta for low speed.

Tools, Equipment and Materials

(i) Instrument box

(ii) Drawing board and T Square

(iii) Pencil (H, HB) and coloured pens (Red, Yellow, and Blue)

(iv) Eraser

(v) Set square

(vi) Drawing sheet (A2 size)

Procedure

(i) Calculate no. of coils : No. of coils = 36

(ii) Calculate No. of coils per phase : No. of coils per

$$\text{phase} = \frac{\text{No. of coils}}{\text{No. of phases}}$$

$$= \frac{36}{3}$$

$$= 12$$

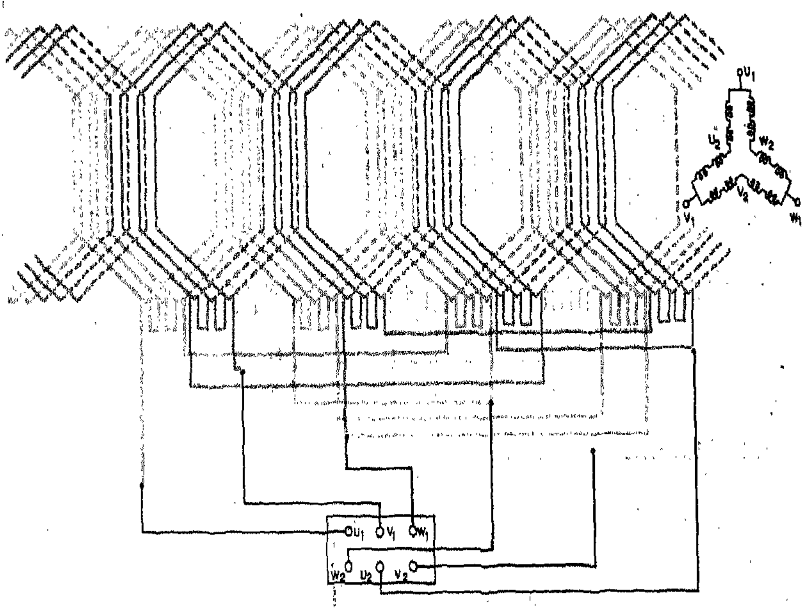


Fig. 13.1 Winding diagram of 36 slot 36 coil double layer short pitched dual speed 3 phase A.C. motor winding

Tabular Record of Observation

No. of coils	*No. of groups*	*Coils/group*
36	12	3

Speed	*Connection*	*Remark*
Low	Series delta	Open u_2, V_2, W_2 terminals Supply connected to u_1, V_1, W_1
High	2 parallel lon star	Short u_1, V_1, W_1 terminals supply connection u_2, V_2, W_{25}

Precaution

(i) Ensure proper connections.

Questions

(i) What is consequitive pole method of speed control ?

(ii) What is the highest speed possible on 50 HZ supply ?

ACTIVITY NO. 14

Impregnation and Baking of Stator Winding of A.C. Motor

Specific Objectives

(i) To understand the effect of preheating

(ii) To know the necessity of dipping the winding in varnish

(iii) To familiarise with different types of insulating varnish

(iv) To develop skills in process of backing

Related Information

After the stator/armature has been wound, soldered banded and tested, it is necessary to varnish the winding. The stator/armature varnished with air drying varnish or baking varnish. Air drying varnish is applied only when backing is undesirable or inconvenient. Before applying dry/baking varnish stator/armature is placed in a baking oven at a temperature of 120° C for about three hours to remove all moisture. This is known as pre-heating. Air drying varnished are: (a) Solventless epoxy resin (b) Polyester varnish. There are two liquids in each packet of dry varnish available in the market. One is resin and another is hardner. Both the liquids should be mixed in a container and used as specified by the manufacturer. Baking varnishes are (a) Shellac (b) Teflon. Varnishing requires different temperatures for baking, generally from 120°C to 140°C for about eight hours.

Dipping of stator/armature is done in the varnish to cease the air bubbles in the winding and baking bonds the entire winding in to a solid mass which is not subject to movement. It also seals the winding against moisture and foreign material and increase the mechanical and dielectric strength of windings.

A chart should be prepared for different stages of baking :

Sl. No.	*Details of motor*	*Name of Manufacturer*	*Type of Varnish*	*Temp. for baking*	*Time for baking required*	*Insulation Resistance*

Tools, Equipment and Materials

Tool

(i) Insulated combination pilers	20 Cms—One
(ii) Insulated screw driver	25 Cms—One
(iii) Knife	20 Cms—One
(iv) Ball Pein Hammer	250 Gms—One

Equipment

(i) Electric oven	
(ii) Stator/Armature	
(iii) Air blower	—200 Watt, 230 Volts—One
(iv) Wall clock	— One
(v) Dummy clock	— One

Materials

(i) Varnish	
(ii) Dipping Tank	
(iii) Stand for dripping	
(iv) Gloves	— One pair

Procedure

(i) Take the stator/armature to be varnished.

(ii) Screw all the cover screws on both the sides of the motor.

(iii) Remove dust from the stator/armature winding by using air blower.

(iv) Place the stator/armature in baking oven at a temperature of 120°C for about three hours.

(v) After cooling, remove the armature from the oven.

A. *Baking Varnish*

(vi) Dip stator/armature in the dipping tank of varnish for half an hour.

(vii) Remove the stator/armature from the tank and keep it on the stand for dripping.

(viii) After the stator/armature has stopped dripping, place it into the baking oven at temperatures as recommended by the manufacturers.

(ix) Switch off the oven when stator/armature is baked.
(x) After cooling, remove it from the oven.

B. *Air Drying Varnish*

(xi) Take both the liquid resin and hardner.
(xii) Shake both the containers to make the solutions homogenous.
(xiii) Open the lids of both the containers.
(xiv) Pour hardner in the container of resin and stir it to make it homogenous.
(xv) Apply the mixture on the winding.
(xvi) Keep the stator/armature in open air for drying.

Precautions

(i) Keep the winding in the dipping tank till all the bubbles ceased
(ii) Use heat resistive gloves while handling the stator/armature
(iii) Do not open the oven immediately after baking is over
(iv) Prepare solution of air drying varnish when stator/armature is ready for varnishing.

Question

(i) State the necessity of varnishing and baking of a motor?

Tabulor Record of Observation

Sl. No.	*Details of motor*	*Type of varnish*	*Starting time*	*Finishing time*	*Temperature*

ACTIVITY NO. 15

Reassembling and Test Running of Rewound A.C. Motor

Specific Objectives

- (i) To be famillíar with procedure and sequence of reassembly
- (ii) To develop skills in reassembling of A.C. motor
- (iii) To develop skill for connection of A.C. motor

Related Information

Reassembling is the converse of the process of assembling. The sequence of operation is also the converse. Reassembly should not result in either excess or deficiency of hardware. A reassembled motor should be free to revolve by hand operation. The assembled motor should be tested for performance on no-load and load. On no-load, the motor should accelerate quickly (1 or 2 sec.) and should coast for a very log period when supply is switched off (a few minutes). While running, there should be no noise or vibration. No load current should not exceed of 25% of the rated current for three phase and 50% of the rated current for single phase motors.

Tools, Equipment and Materials

- (i) Assembly kit
- (ii) Spanner set
- (iii) Screw driver set,
- (iv) Hammer
- (v) Mallet
- (vi) Test lamp
- (vii) Megger
- (viii) Multimeter
- (ix) Tachometer
- (x) Kerosene
- (xi) Cotton Waste
- (xii) Motor grease.

Procedure

- (i) Clean all the metal parts of motor with kerosene.
- (ii) Clean the bearings with kerosene and allow some time to dry.
- (iii) Insert the rotor inside the stator bore carefully.
- (iv) Put the end shields on both sides.
- (v) Tap them by Mallet so that they are properly seated on the edge of the stator frame.
- (vi) Align the marking made on the end cover and frame.

(vii) Tighten the bolts by a few threads.
(viii) Hammer end-covers by wooden mallet at the centre so that cover is seated firmly and uniformly on the edge of the frame.
(ix) Check rotor for free movement.
(x) Tighten all the blots in sequence (opposite bolts should be tightened first.)
(xi) Apply grease to the bearing and grease cap.
(xii) Fix the bolts and tighten them.
(xiii) Put the motor on test bed.
(xiv) Conduct continuity and Resistance test.
(xv) Conduct Insulation resistance test.
(xvi) Connect motor terminals in star or delta as intended.
(xvii) Run it on 'No load' at the rated voltage and not down no load current and speed.
(xviii) Observe its mechanical behaviour.
(xix) Switch off supply and observe time taken by motor to come to rest.
(xx) Disconnect and demount the motor form test bed.

Tabular Record of Observation

RESISTANCE TEST

Winding	*Multi meter reading*	*Remarks*
$u_1 u_2$		
$V_1 V_2$		
$W_1 W_2$		

INSULATION RESISTANCE TEST

Connection	*Megger Reading*	*Remarks*
U_1 Phase to frame		
V_1 phase to frame		
W_1 phase to frame		
u_1 to V_1		
V_1 to W_1		
W_1 to u_1		

NO LOAD TEST

Rated Voltage	*Ammeter Reading*	*Speed*	*Remarks*

Precautions

(i) While cleaning metal parts with kerosene, windings should not come in contract with kerosene.
(ii) Observe scrupulously the correct sequence of assembling.

Questions

(i) Why the opposite bolts should be tightened while assembling?
(ii) State the causes of noise in an A.C. Motor?

ACTIVITY NO. 16

Construction of Cage Rotor Winding of A.C. Motor

Specific Objectives

(i) To study the construction of a Squirrel Cage rotor

(ii) To develop skill for construction of Squirred Cage rotor.

Related Information

A Cage rotor consists of three essential parts :

(a) *Core* :	Core is made up of sheets of high grade silicon steel laminations.
(b) *Shaft* :	Laminated iron core is pressed on the Shaft.
(c) *Squirrel Cage Winding* :	Consisting of Copper bars are placed in slots and are connected to each other by means of copper rings located on both ends of the core.

Loose rotor bars will produce noisy Operation and will not perform desired work. Sparks can be seen between the loose bars and end rings while the motor is running. In some cases the motor may not run. Loose rotor bars may be found by placing the rotor on a growler. The remedy for this condition is resoldering or welding.

Tools, Equipment and Materials

(i)	Growler single phase 220 Volts AC	— One
(ii)	Piece of hacksaw blade	— One
(iii)	Stand for rotor	— One
(iv)	Squirrel Cage rotor	— One
(v)	Soldering Iron 220 V, 100 W	— One
(vi)	Welding set	— One
(vii)	Solder :Tin 60% Lead 40%	— 100 gms
(viii)	Soldering Flux	
(ix)	Emery paper	
(xi)	Brazing rod	— 2 pieces.

Procedure

(i) Check the rotor physically for broken bar short circuited ending

(ii) Solder/weld the broken bar/short circuited ending of the cage rotor.

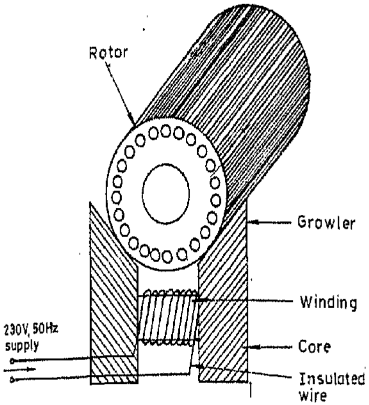


Fig. 16.1 Rotor testing on growler

(iii) Place the rotor on growler
(iv) Switch ON the growler
(v) Place a piece of hacksaw blade on the rotor
(vi) Rotate the rotor gently by hand on the growler so that the blade will remain at the top of the rotor
(vii) Watch the physical condition of the blade
(viii) Mark the points on the rotor where blade vibrate
(ix) Switch off the growler
(x) Remove the rotor from the growler and keep it on a wooden stand
(xi) Repair the loose bars of the rotor by filling the gap with solder
(xii) Again go for growler test
(xiii) Send it for balancing.

Tabular Record of Observation

Details of Motor :

Make ____________
S. No. ____________
Model ____________
H.P. /KW ____________
No. of Phases ____________
Volts ____________
Type of connections ____________
Frequency ____________
RPM ____________

Defects of rotor				
Nature of defects	*Causes*	*Remedies*	*Materials required*	*Removal of defect*

Precautions

(i) Do not run the motor for a long time while observing the defects

(ii) Do not hammer the endrings and surface of the rotor

(iii) After repairing the rotor, balance it on a balancing machine

Questions

(i) What is the necessity of balancing a rotor ?

(ii) What will happen if a motor draws more current than its rated capacity ?

(iii) What will happen when rotor bars are loose ?

ACTIVITY NO. 17

Dismantling of D.C. Motor

Specific Objectives

The student should be able to :

(i) Dismantle the motor
(ii) Record relevant data
(iii) Maintain a long book.

Related Information

Dismantling is the converse of assembling. Hence all the parts removed, bolts loosened, tools used have a part to play in assembly. Hence the sequence followed should be clear and correct. The motor should be kept on a work table of 1.5 meter high so that job can be done in a vertical posture while dismantling, a mark is made by a blade and a scale to facilitate reassembly. The mark is a straight line scratched on the cover and frame. Bolts and studs should be kept in a G.I. steel stray with kerosene so that rust is removed by the time the motor is ready for assembly.

Tools, Equipment and Materials

Tools

(i) Spanner set
(ii) Screw drivers
(iii) Ball pein hammer
(iv) Wooden mallet
(v) Chisel
(v) Punch

Equipment

(i) Lifting and shifting equipment
(ii) Steel tray.

Material

(i) Kerosene oil
(ii) Cotton waste

Procedure

(i) Make punch mark or line mark on the frame and end cover
(ii) Remove bolts of grease cups on both sides of the motor
(iii) Remove blots of end cover on the commutator side
(iv) Remove brushes from the brush holder and the leads from the brush assembly to terminal box
(v) Tap the end cover with a wooden piece and mallet all round the edge

(vi) Pull out the end cover

(vii) Similarly remove end cover on the fan side of the motor

(viii) Put all the studs and bolts in a steel tray containing kerosene to de-rust it

(ix) Note down name plate details.

Tabular Record of Observations

Record motor data in the following table

Type of motor	*H.P.*	*Speed*	*Class of Insulation*	*Rating*	*V*	*I*

Precautions

(i) Never hit the end shields by hammer lest the shield may crack

(ii) Ensure that the brushes are taken out of brush holder before removing end cover

(iii) Ensure that the gap all round is uniform while hitting the end cover

(iv) If the bolts are all rusted, don't forcibly loosen them. Drench them with kerosene.

Questions

(i) What are the various types of motor enclosures ?

(ii) Name the methods of mountings ?

(iii) Why do we prefer ball bearing at the non-driving end and roller bearing at the driving end ?

(iv) What is the nomenclature for D.C. machine terminals as per BIS.

ACTIVITY NO. 18

Removal of Burnt Winding Coils from Armature of D.C. Motor

Specific Objectives

The student should be able to :

(i) Know the methods of softening the winding by heating

(ii) Strip the armature winding

(iii) De-solder the end connections at the commutator risen.

Related Information

The armature is a rotating part. It houses the winding. It is actually an electric circuit linked to the magnetic circuit. The electric circuit is connected to the commutator. The commutator is a combination of number of split rings to convert the DC supply to AC in the armature, with the help of stationary brushes. The brushes are usually graphitised carbon. The brushes are made only of graphite since it is a resistance material preventing short circuiting of the coil under commutation. Graphite is not harder and hence it will not scratch commutator. Graphite also acts as a lubricant. It can withstand arching and sparking.

Any winding will be hard and difficult to remove. To facilitate easy stripping, armature is heated in an electric oven or by a lamp of 200W. Heating makes the winding soft and supple. Removal becomes easier.

Tools, Equipment and Materials

(a) *Tools* :

(i) Chisel

(ii) Cutting plier

(iii) Screw driver

(iv) Soldering Iron

(v) Hammer

(b) *Equipment* :

(i) Electric oven

(ii) 200 W lamp set.

(c) *Material* :

(i) Armature.

Procedure

(i) Heat the armature by external means.
(ii) De-solder connections at the commutator risers.
(iii) Remove the binding wire on the overhangs of armature.
(iv) Remove the fibre wedges.
(v) Chisel out the coils at the overhang on the commutator side.
(vi) Tug out each coil from slot from the other side of the overhang using a long screw driver.
(vii) Note down relevant details of the winding and coil.
(viii) Preserve one coil for preparing former .

Precautions

(i) Never overheat the winding
(ii) Do not be harsh or rash while stripping as laminations are distorted at the ends
(iii) De-solder carefully avoiding spillage of solder on commutator mica separators.

Questions

(i) How do you see SWG to determine the size of a conductor ?
(ii) What are the enamel materials used for copper wire ?
(iii) Why do we use only annealed copper and not hard drawn copper for windings ?
(iv) What are the demerits of aluminium as winding material ?

Tabular Record of Observation

SWG	*No. of Coils*	*Turns per Coil*	*Type of Winding*	*Any Other Detail*

ACTIVITY NO. 19

Removal of Burnt Field Coils from Stator of D.C. Motor

Specific Objectives

The student should be able to :

(i) Remove the field poles from the yoke

(ii) Remove the field coils from the poles.

Related Information

The yoke acts as a support to the poles and as a path for flux. The yoke also acts as an enclosure. The pole shoe spreads the flux and also supports the field coil. The field coils are of two types:

(1) Shunt coils (2) Series coils. The field coils produce m.m.f. and do not consume much power. The poles may be dovetailed to the yoke or may be bolted to the yoke.

Tools, Equipment and Materials

(i) Spanner set

(ii) Screw drivers

(iii) D.C. motor

(iv) Kerosene oil

(v) Steel Tray

(vi) Oven

Procedure

(i) Put kerosene on all the bolts of yoke and allow sometime for kerosene to act

(ii) Unscrew bolts sequentially

(iii) Remove the poles with coils

(iv) Remove the coils from poles

(v) Note down the gauge of wire and the number of turns.

Tabular Record of Observations

SWG	*Number of turns*	*Size of coil*

Precautions

(i) If the bolts are rusted, do not forcibly unscrew. Put some kerosene and allow sometime for kerosene to act on rust.

Questions

(i) Why are the yoke and poles of solid construction and not laminated unlike armature ?

(ii) What are commutating coils ?

(iii) Why are poles stationery and armature is revolving part in a D.C. motor and not vice versa ?

ACTIVITY NO. 20

Preparation of Slot and Slot Insulation of D.C. Motor

Specific Objectives

The student should be able to:

(i) Choose correct material for slot insulation
(ii) Know the proper dimensions for slot lining, separator and top cover
(iii) Shape slot insulation.

Related Information

The slot insulation material is governed by temperature rise i.e., by class of operation. The common insulator used are press paper called leatheroid or kheddhide or elephentide; empire cloth or cambric cloth; polyester paper called Melinex or Mylar; presspaper with polyester film called symax.

Tools, Equipment and Materials

Tools

(i) Scissors
(ii) Steel scale.

Materials

(i) Insulation paper say Symax
(ii) Adhesive tape.

Procedure

(i) Measure axial length of armature L
(ii) Measure dimensions of slot width W and depth H
(iii) Prepare standard pieces of slot lining separator and cover paper
(iv) Cut the paper to required size for slot insulation
(v) In composite insulation, say press paper and empire cloth the two strips are tapid at the edges.

Tabular Record of Observations

Length of Armature	*Width of Slot*	*Height of Slot*	*No. of Slots*

Precautions

(i) Observe the original insulation material provided carefully and scrupulously adopt the same material for reinsulation.

(ii) Never scratch the insulation while cutting or bending it.

(iii) Prepare the insulation on a clean surface so that it is clean and dust free.

Questions

(i) Prepare a table of slot insulation materials with their commercial and technical names.

(ii) Why extra slot insulation or excessive insulation is not provided in slots though it provides better dielectric strength.

ACTIVITY NO. 21

Construction of Simplex Lap Winding of Armature of D.C. Motor

Specific Objectives

The student should be able to :

(i) Calculate pitches

(ii) Prepare the winding table

(iii) Draw the developed winding diagram

(iv) Draw the sequence diagram

(v) Locate the position of brushes

(vi) Connect leads to terminal box.

Related Information

In a simplex lap winding, the Back pitch and Front pitch are nearly equal to the pole pitch. They are odd numbers and their difference must be equal to 2. If Y_s is greater than Y_f, it is a progressive winding. If Y_s is less than Y_f, it is a retrogressive winding. The number of parallel paths in armatur are equal to number of poles. The number of brushes should be equal to number of poles. The brushes lie in the position where they get connected to conductors in the interpolar gaps, so that they derive the highest potential difference.

Tools, Equipment and Materials

(i) Drawing bard and T square

(ii) Instruments box

(iii) Pencil and eraser

(iv) Drawing sheet A_2 size.

Procedure

Consider 4-pole 24-slots single layer simplex lap winding of a D.C. motor.

(i) Calculate pitches

$$Y = \frac{Z}{P} = \frac{24}{4} = 6$$

Y_m and Y_f should be near to 6

$Y_z - Y_f = 2$

Y_s and Y_f should be odd number.

Hence $Y_s = 7$ and $Y_f = 5$ for progressive lap winding single layer.

(ii) Draw 24 conductors (slots)

(iii) Mark poles over 70% of the pole

pitch i.e. 0.7 × 6 = 4.2, say 4 conductors

(iv) Distribute the remaining conductur in the interpolar gaps, 2 conductors in each gap totally 8 conductors

(v) Mark the direction of emf.

(vi) Complete the winding as per the winding table

(vii) Draw the sequence diagram

(viii) Mark the direction of emfs.

(ix) Draw the commutator segments. Number of segments are equal to number of coils

(x) The brushes are located at the meeting and separating points of emfs $(+)^{ve}$ for meeting point and $(-)^{ve}$ for separating point

(xi) Connect positive brushes together and negative brushes together

(xii) Bring out +ve and -ve terminals and label as A_1 and A_2.

Tabular Record of Observations

1 + 7 = 8	8 — 5 = 3
3 + 7 = 10	10 — 5 = 5

and so on, until the winding returns to 1.

1 - 8 — 3 - 10 — 5 - 12 — 7 - 14

— 9 - 16 — 11 - 18 — 13 - 20 — 15 - 22

— 17 - 24 — 19 - 2 (26)

— 21 - 4 — 23 - 6 — 25 (1)

Here the table starts from ± 1 and ends with 25 or 1. There are 24 numbers from 1 to 25 (1). Hence no conductor is emitted.

Conductor under each pole = 4

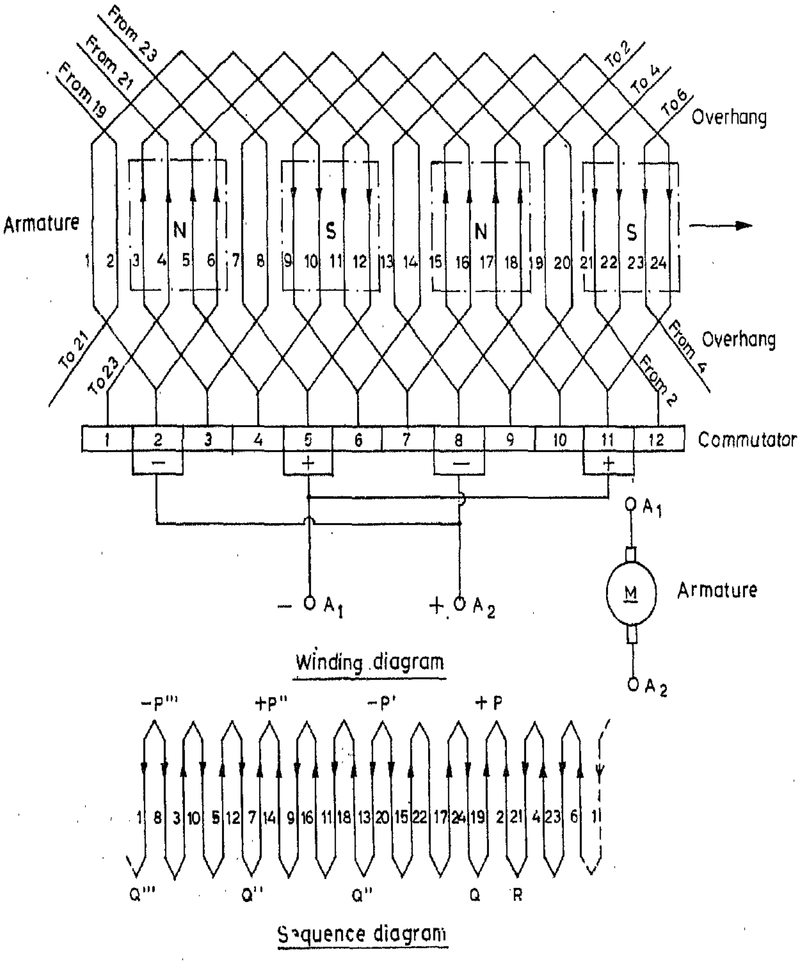
Conductors under four poles = 4 × 4 = 16

Conductor under interpoles = 24—16 = 8

Interpolar conductors = 2

If the emf under N pole is reckoned upwards, then that under south pole should be reckoned downwards.

Developed winding diagram of a 4 pole 24 slot single layer simplex progressive lap winding of armature of D.C. motor is illustrated in Fig. 21.1.



Winding diagram

Sequence diagram

Note – 1. The meeting and seperating points are at the back of the sequence diagram. For a point P, there are two points Q and R for brushes. If Q is chosen, the same should be done for other points P', P'' and P'''.

2. Directions are not marked for interpolar conductors, they are assigned direction depending upon their vicinity to poles to arrive at polarity.

Fig. 21.1 Single layer simplex lap winding of a 4 pole 24 slot D.C. motor

Precaution

(i) Do not mark directions for conductors in interpolar gaps.

Question

(i) What are equaliser bars ?

Construction of Duplex Lap Winding of Armature of D.C. Motor

Specific Objectives

The student should be able to :

(i) Calculate pitches
(ii) Prepare winding table
(iii) Draw the developed winding diagram
(iv) Draw the sequence diagrams
(v) Locate the position of brushes
(vi) Bring leads to the terminal box

Related Information

In a duplex winding, it is possible to get higher current for the same number of poles, same frame size and same rating. In a 4 pole duplex winding, there will be 8 parallel paths instead of 4 paths as in simplex winding. The brushes bridge two adjacent segments. The pitches are calculated as for a Lap winding. But $Y_b - Y_f = 2n$ where n = 1 for Simplex, n = 2 for Duplex, n = 3 for triplex. There will be two winding tables and sequence diagram. There will be two identical symmetrical windings in the same armature. The first winding starts from conductor 1 and ends on 1. The second winding starts from conductor 3 and ends on 3.

Tools, Equipment and Materials

(i) Drawing board and T square or drafter
(ii) Instruments box
(iii) Pencil and eraser
(iv) Drawing sheet A_2 size

Procedure

Consider 4 pole 24 slots double layer duplex lap winding of a D.C. motor.

(i) Calculate pitches

$$Y = \frac{Z}{P} = \frac{24 \times 2}{4} = \frac{48}{4} = 12$$

Y_b and Y_f should be odd numbers nearby equal to pole pitch

$Y = 12$, But $Y_b - Y_f = 2n$. Here $n = 2$

$Y_b = 13$ and $Y_f = Y_b - 2 \times 2 = 13 - 4 = 9$

$\therefore\ Y_b = 13$ and $Y_f = 9$

(ii) Draw 48 conductors in 24 sets having one full line and one dotted line. Full line is top conductor and dotted line is bottom conductor; one full and one dotted line together represents a slot

(iii) Mark poles spanning 70% i.e. 0.7 of the poles pitch $0.7 \times \frac{24}{4} = 0.7 \times 6 = 4.2$ i.e. 4 slots. i.e. 8 conducters

(iv) Distribute remaining conductors in the interpolar gaps

(v) Mark direction of emf's

(vi) Complete the winding as per the winding table

(vii) Draw sequence diagrams

(viii) Mark the direction of emf's

(ix) Draw the commutator segments. 24 segments (number of segments is equal to number of coils)

(x) Locate brushes at the meeting points of emfs (+brush) and at the separating points (—brush)

(xi) Connect all positive brushes together to get positive terminal. Connect all negative brushes connected together to get negative terminal. Level them as A_1 and A_2.

Tabular Record of Observations

1 + 13 = 14 ; 14 – 9 = 5

5 + 13 = 18 ; – 18 — 9 = 9 and so on

1 – 14 — 5 – 18 — 9 – 22 — 13 – 26

— 17 – 30 — 21 – 34 — 25 – 38 — 29 – 42

33 – 46 — 37 – (50) 2 – 41 — 6 – 45

— 37 – 50 — 2 – 41 — 6 – 45 — 10 - (49)1

3 – 16 — 7 – 20 — 11 – 24 — 15 – 28

— 19 – 32 — 23 – 36 — 27 – 40 — 31 – 44

— 35 – 48 — 39 – 4 — 43 – 8 — 47– 12

— (51) 3

Here one winding starts from conductor 1 and ends on 1 itself after completing the path through 24 conductors. The other winding starts from conductor 3 and closes on 3 itself after completing the path through 24 conductors.

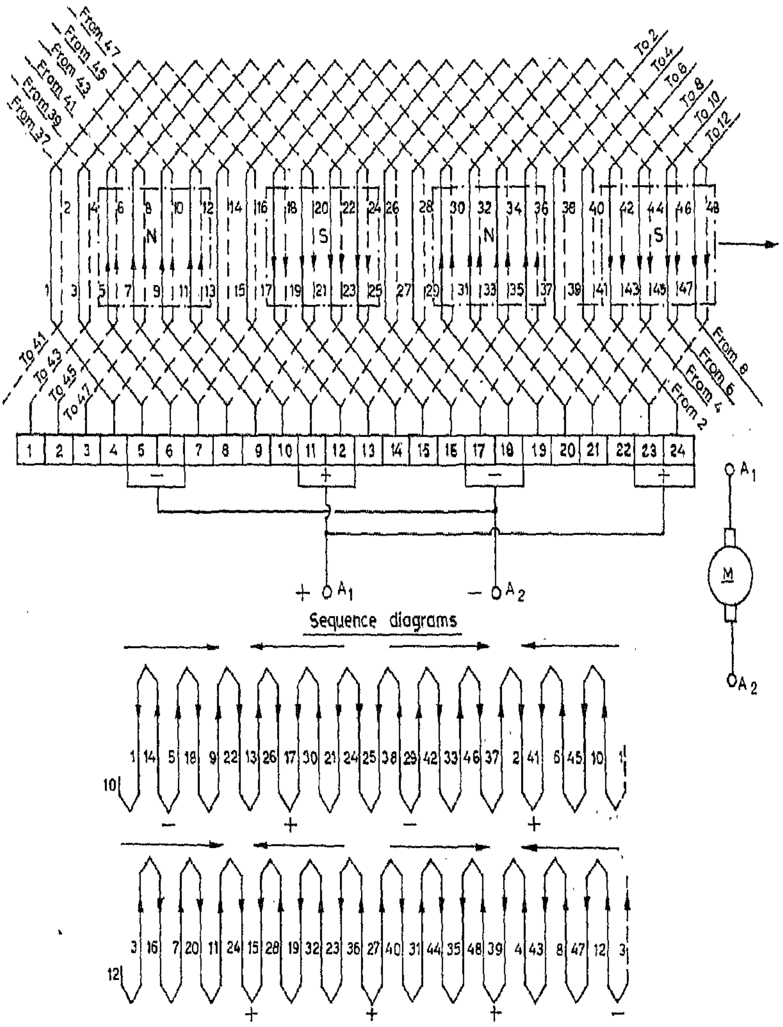


Fig. 22.1. Double layer duplex lap winding of a 4 pole 24 slot D.C. Motor

Precaution

(i) Ensure width of brushes is slightly more than two segments.

Question

(i) How many parallel paths will there be in a 4 pole Triplex Lap Winding?

ACTIVITY NO. 23

Construction of Simplex Wave Winding of Armature of D.C. Motor

Specific Objectives

The student should be able to:

- (i) Calculate pitches
- (ii) Prepare winding table
- (iii) Draw developed winding diagram
- (iv) Draw the sequence diagram
- (v) Locate the position of brushes
- (vi) Bring leads to terminal box

Related Information

A wave winding is a closed winding. It gives a higher voltage and a smaller current than a lap winding for the same slots and conductors. It has only two parallel paths regardless of number of poles. Number of brushes are equal to number of poles to reduce the current per brush.

In a Simplex wave winding, the coil pitch $Y = \frac{Z \pm 2}{P}$ Both Y_b and Y_f should be odd numbers. They should be nearer to pole pitch, $Y_b - Y_f$ must be equal to two.

Tools, Equipment and Materials

- (i) Drawing table and T square
- (ii) Instruments Box
- (iii) Pencil and eraser
- (iv) Drawing sheet A_2 size

Procedure

Consider 4 pole 26 slot single-layer simplex wave winding of a D.C. motor.

(i) Calculate pitches.

(a) $Y = \frac{Y_b + Y_f}{2} = \frac{Z \pm 2}{P}$ or $\frac{26 \pm 2}{4}$

$\therefore \quad Y = \frac{Y_b + Y_f}{2} = \frac{28}{4}$ or $\frac{24}{4}$

$Y \pm 7$ or 6

(b) $\therefore \quad \frac{Y_b + Y_f}{2} = \underline{7; Y_b = Y_f = 7}$

(c) $\therefore \quad \frac{Y_b + Y_f}{2} = \frac{6; Y_b + Y_f = 12}{Y_b - Y_f = 2}$

$\therefore \quad \underline{\underline{Y_b = 7 \text{ and } Y_f = 5}}$

Both sets of pitches may be used using $Y_b = 7$ and $Y_f = 5$.

(ii) Draw 26 slots or 26 conductors.

(iii) Mark poles spanning 70% of the pole pitch. 70% or 0.7 of $\frac{26}{4}$ is 4.55 say 5 conductors or 5 slots

(iv) The remaining slots are left at the mercy of interpolar gaps i.e. 6 conductors at the interpolar gaps

(v) Mark direction of emfs

(vi) Complete winding as per the winding table

(vii) Draw the sequence diagram

(viii) Mark the direction of emf

(ix) Draw the commutater segments 13 segments totally

(x) Locate the brushes at the meeting point and at the separating points

(xi) Label the terminals as A_1 and A_2

Tabular Record of Observations

1 + 7	= 8	8 + 5	= 13
13 + 7	= 20	20 + 5	= 25
25 + 7	= (32) 6	6 + 5	= 11
11 + 7	= 18	18 + 5	= 23
23 + 7	= (30) 4	4 + 5	= 9
9 + 7	= 16	16 + 5	= 21
21 + 7	= (28) 2	2 + 5	= 7
7 + 7	= 14	14 + 5	= 19
19 + 7	= 26	26 + 5	= (31) 5
5 + 7	= 12	12 + 5	= 17
17 + 7	= 24	24 + 5	= (29) 3
3 + 7	= 10	10 + 5	= 15
15 + 5	= 22	22 + 5	= (27)1

Here all the 26 conductors have been accounted. The winding starts from 1 and ends at 1.

Developed Winding Diagram of A 4 Pole 26 Slot Single Layer Simplex Wave Winding of a D.C. motor is illustrated in Fig. 23.1.

Precautions

(i) The conductors in each parallel path must be almost equal.

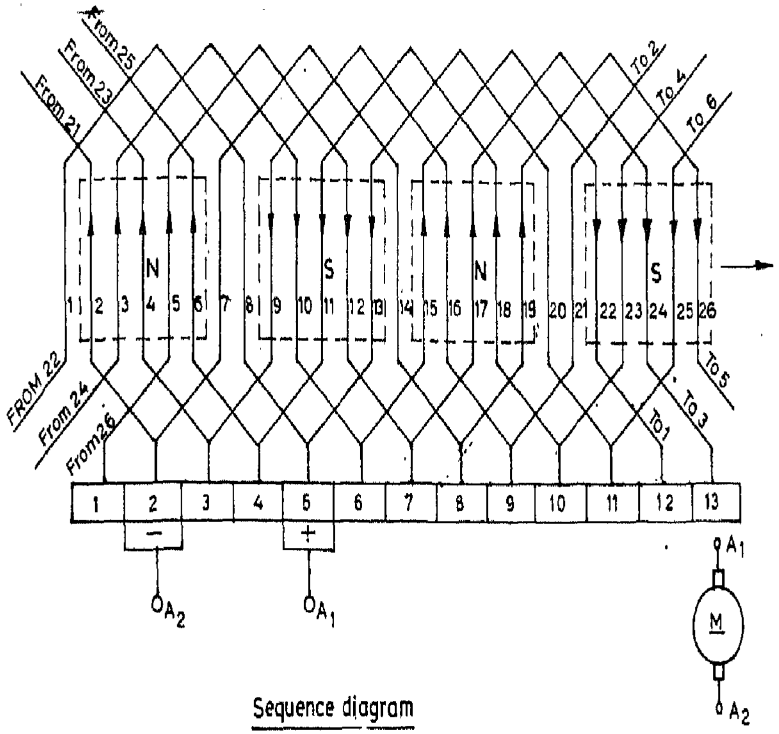
(ii) For any even number of conductors wave winding is not possible.

Questions

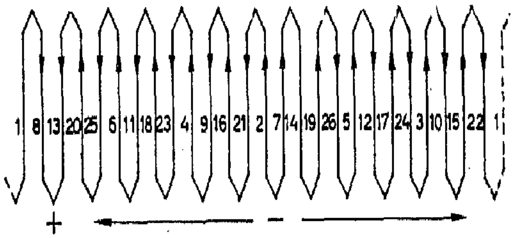
(i) What is a dummy coil?

(ii) When and where a dummy coil is used?

(iii) What happens if the coil instead of being dummy is not inserted in the slot at all?



Sequence diagram



NOTE —Conductors 1,7,8,14,20 and 21 are in interpolar gaps. EMFS in them is negligible. But as 7 is nearer to north its EMF is taken as upwards, that of 8 downwards. No direction is marked for 1 and 14. The flow of current is from 16 towards left and from 21 towards right meeting at 8 and 13.

Fig. 23.1 26 slot 4 pole single layer simplex wave winding of a D.C. Motor

ACTIVITY NO. 24

Construction of Duplex Wave Winding of Armature of D.C. Motor

Specific Objectives

The student should be able to:

(i) Calculate pitches

(ii) Prepare the winding table

(iii) Draw the developed winding diagram

(iv) Draw sequence diagram

(v) Locate position of brushes

(vi) Connect leads to the terminal box

Related Information

A duplex wave winding provide double the number of parallel paths than a corresponding simplex wave winding i.e. 4 paths regardless of number of poles.

$$Y = \frac{Y_b + Y_f}{2} = \frac{Z \pm 2n}{P}$$

Here n = 1, 2, 3 etc. for simplex, duplex and triplex winding respectively.

Tools, Equipment and Materials

(i) Drawing Board and T square

(ii) Instruments box

(iii) Pencil and eraser

(iv) Drawing sheet A_2 size

Procedure

Consider 4 pole 22 slot double layer duplex wave winding of a D.C. Motor.

(i) Calculate winding pitches.

$$Y = \frac{Y_b + Y_f}{2} = \frac{Z \pm 2n}{P}; \text{ here } n = 2$$

$$\therefore Y = \frac{22 \times 2 \pm 2 \times 2}{4} = \frac{44 \pm}{4}$$

$$= \frac{48}{4} \text{ or } \frac{40}{4} = 12 \text{ or } 10$$

Choose Y = 12

$$Y = \frac{Y_b + Y_f}{2} = 12 \therefore Y_b + Y_f = 24$$

$$Y_b - Y_f = 2; \therefore Y_b = \frac{26}{2} = 13$$

$$Yf = 13 - 2 = 11$$

$$\therefore \underline{\underline{Y_b = 13; Y_f = 11}}$$

(ii) Draw 44 conductors i.e. 22 sets of conductors having full line and dotted line to represent double layer. Full line corresponds to top conductor and dotted line to bottom. conductor.

(iii) Mark the poles spanning 70% of pole pitch, i.e. $\frac{22}{4} = 5.5$. is the pole pitch in terms of slots 70% of 5.5 is 3.85 say 4 slots. Totally 16 slots, 4 slots under every pole.

(iv) Distribute remaining 6 slots in the interpolar gaps in the order of 2—1—2—1.

(v) Mark direction of emfs.

(vi) Complete the windings as per the winding tables.

(vii) Draw sequence diagrams.

(viii) Draw the direction of emfs in the sequence diagram.

(ix) Draw the commutator segments 22 segments totally for 22 coils.

(x) Locate the brushes at the meeting and separating points as per the two sequence diagrams.

(xi) Each brush bridges two segments.

(xii) Label the terminals as A_1 and A_2

Tabular Record of Observations

TABLE NO. 1

1 + 13 = 14	14 + 11 = 25
25 + 13 = 38	38 + 11 =49
5 + 13 = 18	18 + 11 = 29
29 + 13 = 42	42 + 11 = (53) 9
9 + 13 = 22	22 + 11 = 33
33 + 11 = (46) 2	2 + 11 = 13
13 + 13 = 26	26 + 11 = 37
37 + 13 = (50) 6	6 + 11 = 17
17 + 13 = 30	30 + 11 = 41
41 + 13 = (54)18	10 + 11 = 21
21 + 13 = 34	34 + 11 = (45) 1

TABLE NO. 2

3 + 13 = 16	16 + 11 = 27
27 + 13 = 40	40 + 11 = (51) 7
7 + 13 = 20	20 + 11 = 31
31 + 13 = 44	44 + 11 = 55
11 + 13 = 24	24 + 11 = 35
35 + 13 = (48) 4	4 + 11 = 15
15 + 13 = 28	28 + 11 = 39
39 + 13 = (52) 8	8 + 11 = 19
19 + 13 = 32	32 + 11 = 43
43 + 13 = (56) 12	12 + 11 = 23
23 + 13 = 36	36 + 11 = (47) 3

Developed Winding Diagram and Sequence Diagrams. Same illustrated in Fig. 24.1.

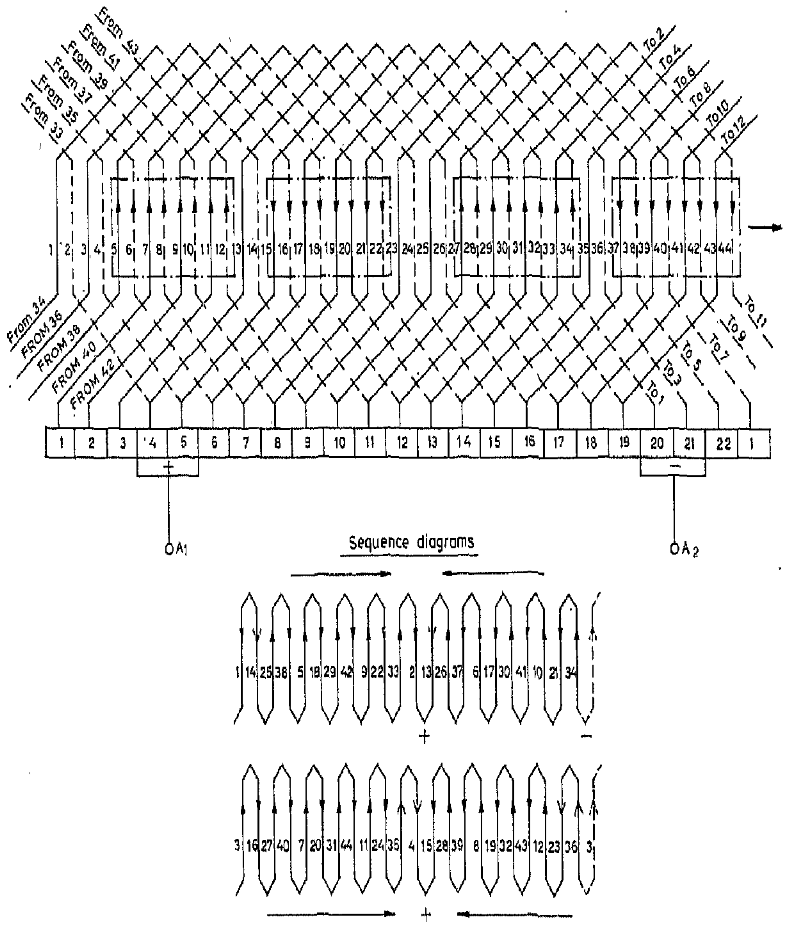


Fig. 24.1 22-slot 4-pole double layer duplex wave winding of a D.C. Motor

Precaution

(i) Care should be taken for preparing winding table.

Question

(i) What is the main advantage of multiplex winding over simplex lap or wave winding?

ACTIVITY NO. 25

Preparation of Coils of Armature of D.C. Motor

Specific Objectives

The student should be able to:

(i) Prepare former for a given coil size
(ii) Prepare coils and shape it

Related Information

Former is the wooden frame on which conductor is wound to produce coils. The size and shape of the former is determined by pitch, length of armature, and overhang. The conductor material is annealed electrolticalIy pure tough pitched copper (EPTPA) insulated with an enamel (resin). The enamels used are: (a) polyvinyl acetate, (b) polyester, (c) polyesteramide, (d) Alkyd (e) Polymide and (f) Silicone resins. They are of 48 to 68 microns thick. In situations with heavy vibrations, the most flexible (least brittle) insulation is cotton. Hence D.C.C. wires only are used for such situations.

Tools, Equipment and Materials

(i) Carpentary tools
(ii) Wood working lathe and drilling machine
(iii) Teak wood, cotton tape, cotton thread

Procedure

(i) Prepare wooden former for a standard coil
(ii) Prepare coils by hand winding or on a motor driven spindle
(iii) Tie the coils at the corners by a cotton tape
(iv) Stack the coils in a wooden or plastic tray

Tabular Record of Observations

SWC of Wire	*No. of turns per coil*	*No. of Coils*

Precautions

(i) Avoid scratches on wires
(ii) Maintain proper tension during winding

Questions

(i) Instead of a coil of 14 SWG, calculate the gauge of wires for two coils in parallel combination for same current rating.

ACTIVITY NO. 26

Preparation of Field Coils of D.C. Motor

Specific Objectives

The student should be able to:

- (i) Prepare wooden bobbin or former
- (ii) Prepare field coils, shunt and series coils

Related Information

Formers were wooden frames operated manually or motorised to wind the conductor to form coils. The size and shape of the former is determined from an old burnt coil. The shunt field coil consists of larger number of turns (thousands of higher gauge (20 to 28 SWG) and series field consists of smaller number of turns (Tens or hundreds) of lower gauge (8 or 14 SWG) or strip copper.

Tools, Equipment and Materials

- (i) Wood working machines
- (ii) Carpentry tools
- (iii) Teak wood, cotton tape, bolt and nut
- (iv) Enamelled wire
- (v) Air drying varnish

Procedure

- (i) Prepare a wooden former as per the old coil size
- (ii) Prepare the coils using the required gauge of enamelled wire
- (iii) Apply interlayer insulation of air drying varnish
- (iv) Tape the coils
- (v) Stack it in a wooden tray

Tabular Record of Observations

SWG of Conductor	*No. of turns*	*No. of coils*

Precautions

- (i) Avoid scratches on anamelled wire during winding of coils
- (ii) Ensure proper tension on wire during winding

Questions

- (i) What is interlayer insulation?
- (ii) For interlayer insulation, which material do you prefer — Tissue paper (Hi-Mag paper) or Air Drying Varnish?

ACTIVITY NO. 27

Insertion of Armature Coils and End Connections to Commutator of D.C. Motor

Specific Objectives

The student should be able to:

(i) Insert armature coils
(ii) Solder coil ends to the commutator riser as per the winding diagram.

Related Information

While inserting the coils, polyester paper backing should be used to avoid scratch at the tip of the slots. Fibre wedges are used to push the conductor. In double layer, the bottom conductors are first inserted. For soldering the ends, the enamel should be removed by the use of sand paper and not emery. Never use knife as it may damage the conductor.

Tools, Equipment and Materials

(i) Armature winding tools
(ii) Polyester paper
(iii) Soldering gun 100 W
(iv) Resin core solder 68 : 48
(v) Cotton waste, sand paper
(vi) Fibre wedge

Procedure

(i) Insert guide paper first in the slot
(ii) Spread out the bottom conductor and draw in sidewards
(iii) Push it in and seal it properly by fibre wedge and tape it
(iv) Push in the separate insulator
(v) Insert the top conductor
(vi) Insert the top insulator
(vii) Consolidate the conductors. Tape and seal the conductors
(viii) Drive fibre wedges to position
(ix) Route the ends of each coil properly
(x) Remove enamel seal in the riser properly
(xi) Solder the conductor ends to the commutator riser
(xii) Remove extra solder, solder spilled around, and clean commutator.

Tabular Record of Observations

Slot Number	*Conductor Number*	*Commutator Segment Number*

Precautions

(i) Avoid scratches on enamel wire during insertion of coils

(ii) Soldering must be done within specified time

Questions

(i) What is tinning of conductor?

(ii) What is the purpose of soldering flux?

(iii) What is dry solder?

(iv) What happens if solder gets wedged between segments inadvertently?

ACTIVITY NO. 28

Placement of Field Coils of D.C. Motor

Specific Objectives

The student should be able to:

(i) Insulate the poles
(ii) Place the shunt field coils
(iii) Place the series field coils
(iv) Connect the shunt coils in series and series coils in series for proper polarity

Related Information

The field coils are concentrated windings. They are connected in series so that one pole becomes 'N' pole, the next pole becomes 'S' pole. This can be tested by a magnetic compass. A small D.C. voltage of 12 V may be applied. If the polarity is not correct, interchange the leads of that coil. Magnetic polarity test is illustrated in Fig. 28.1.

Tools, Equipment and Materials

(i) Electrician's tools
(ii) Magnetic compass
(iii) Battery
(iv) Switch
(v) Insulating paper (press paper), press board or presspahn, cotton tape, adhesive tape, sleeve.

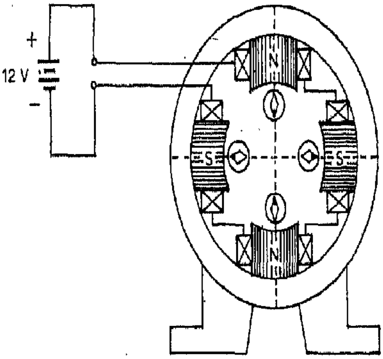


Fig. 28.1 Magnetic Polarity Test

Procedure

(i) Insulate the poles by press paper
(ii) Insert bottom seating paper on the pole shoe
(iii) Shape the field coils on a wooden former
(iv) Impregnate and bake the coils
(v) Place the coils on the poles
(vi) Place the top insulation paper
(vii) Fix the pole (with coil) to the yoke by bolt

(viii) Sleeve the leads

(ix) Connect the shunt field coils in series

(x) Connect the series field coils in series

(xi) Join the leads and solder the joints, properly, route the leads

(xii) Push the sleeves over the joints so as to insulate them

(xiii) Conduct polarity test

(xiv) Label the leads of shunt and series fields

Tabular Record of Observations

Polarity *Coil*	*N*	*S*	*N*	*S*
Shunt				
Series				

Precaution

(i) Ensure that the coils are not reversed leading to wrong polarity.

ACTIVITY NO. 29

Testing of Armature Winding and Field Coils of D.C. Motor

Specific Objective

The student should be able to:

(i) Test armature winding and field coils.

Related Information

The test procedure for armature and field windings are almost the same. These tests are (a) continuity test, (b) polarity test for pole formation (c) Insulation test, (d) drop test.

The winding is tested for continuity by a test lamp. If the lamp burns bright, there is continuity, otherwise it is open circuited. This is illustrated in Fig. 29.1.

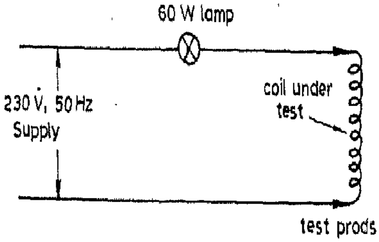


Fig. 29.1 Continuity Test

Magnetic polarity test is done by a magnetic compass when poles are connected to low voltage D.C. (12 V). It should show North, South, North, South alternately. Otherwise the leads of the coil has to be interchanged. This is illustrated in Fig. 29.2.

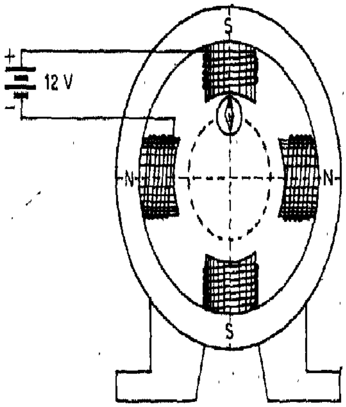


Fig. 29.2 Magnetic Polarity Test

Insulation Resistance test is done by a megger and reading should be 1 Meg ohm.

Drop test for armature is done by passing a low voltage D.C. current across two commutator segments preferably at 90° apart. The drop across two segments is measured by a low voltage D.C. Voltmeter and test prods. The reading should be same as the armature is rotated and reading noted across the segments. It ensures that all the coils are intact without any short.

Tabular Record of Observations

	Continuity Test	*Polarity Test*	*Megger Test*	*Drop Test*
Armature Winding	OK	—	OK	OK
Field Winding	OK	OK	OK	—

Tools, Equipment and Materials

Test kit consisting of:

(i) Test lamp
(ii) Megger ohm meter 1000 V
(iii) Low range PMMC voltmeter
(iv) Magnetic compass
(v) 12 V battery (lead acid)
(vi) Test prods

Procedure

(i) Test the field winding for continuity
(ii) Test the field winding for magnetic polarity
(iii) Test the field and armature winding for insulation resistance
(iv) Test the armature for short in individual coils, loose connection, bad soldering

Precautions

(i) Follow test procedures scrupulously
(ii) Be safety conscious
(iii) Adjust instrument before use

Questions

(i) What is the effect of temperature on the value of insulation resistance ?
(ii) Is resistance measurement a better method for testing continuity of a coil than the test lamp ?

ACTIVITY NO. 30

Impregnation and Baking of Armature and Field Coils of D.C. Motor

Specific Objectives

The student should be able to:

(i) Appreciate the need for impregnation and baking
(ii) Choose the proper resin varnish
(iii) Do impregnation and baking

Related Information

Drying, impregnation and baking is the final part of rewinding. While drying, all the moisture is expelled producing partial vacuum. As the winding is dipped, it sucks varnish as it were, due to the partial vacuum and fills up voids. It is allowed to drip and finally baked. The advantages of baking are increase in dielectric strength and mechanical strength of coil. It becomes very strong and can withstand mechanical vibrations and shocks. As the coil is very homogeneous, it does not absorb moisture. As the surface is glazy, dust and dirt are not collected. Thermal conductivity is better and hence cooling is better and life will be longer.

The duration and temperature of baking is very important. It depends on the type of varnish used.

Tools, Equipment and Materials

(i) Drying oven 2 KW capacity /200W lamps
(ii) A jute covering
(iii) Insulating varnish
(iv) Steel tray

Procedure

(i) Dry the armature/field coils for 2 hours in oven
(ii) Dip it in insulating varnish bath immediately for two minutes
(iii) Take it out from varnish bath and allow it to drip for 1 minute
(iv) Bake it for 8 hours at 120°C (for polyster varnish)

Tabular Record of Observation

Drying		*Dipping*	*Dripping*	*Baking*	
Time	Temperature	Time	Time	Time	Temperature
2 hours	90°C	2 minute	1 minute	2 hours	140°C

Precautions

(i) The varnishing room must not be near working spot

(ii) It should be well ventilated preferably with exhaust fan

(iii) Do not come in contact with hot varnish as it may lead to skin troubles

Questions

(i) Prepare a list of electrical impregnating varnishes locally available.

(ii) What is Situmen? Is it thermo plastic or thermosetting?

(iii) What is the effect of improper drying and improper preheating?

ACTIVITY NO. 31

Reassembling and Test Running of D.C. Motor

Specific Objectives

The student should be able to:

- (i) Appreciate the need for testing
- (ii) Re-assemble a D.C. motor
- (iii) Test run a D.C. motor

Related Information

Reassembling is the converse of the process of disassembling. The sequence is also the converse. After proper reassembling, the rotor should be very free to rotate by hand, should not produce squeaks or sounds. It is tested to know its performance without supply and then with supply. The tests conducted are : (a) Continuity test by test lamp, (b) Resistance measurement by ohm meter, (c) Insulation resistance by megger ohm meter, (d) No load running.

Tools, Equipment and Materials

- (i) Hammer,.Mallet, Spanners, Screw driver
- (ii) Megger ohm meter, techometer, test lamp, AVO meter
- (iii) Cotton waste, motor grease
- (iv) Kerosene oil
- (v) Baking oven

Procedure

- (i) Clean all the metal parts of stator and rotor by kerosene
- (ii) Clean the ball bearings with kerosene and dry it
- (iii) Put grease to the bearings and grease cup
- (iv) Connect the brush leads to the terminal box by PVC cable
- (v) Insert armature in stator
- (vi) Put the end covers properly seated in the recess on yoke
- (vii) Place the brushes in position and release the springs on brushes
- (viii) Adjust spring tension
- (ix) Align the marks on the end covers and yoke
- (x) Thread the studs on the end covers
- (xi) Hit the end covers gently at the centre to seat it firmly on yoke by mallet

(xii) Tighten bolts in sequence on both side
(xiii) Put the grease cups
(xiv) Tighten the studs
(xv) Check for free movement of rotor
(xvi) Measure resistance of armature, shunt and series fields.
(A_1, A_2), Resistance of armature
(E_1, E_2), Resistance of shunt field
(D_1, D_2) resistance of series field
(xvii) Dry the motor, bake it to 75°C. Put it to megger test. It should show a minimum of 1 Megohm at 75°C
(xviii) Run it at no lead as a shunt motor. It should run freely without any vibration and noise
(xix) The no-load current should be 10% of the rated value
(xx) Switch off the supply. It should rotate for a longer time, say 3 or 4 minutes

Tabular Record of Observations

Resistance Measurement

	Armature	*Shunt*	*Series*
	A_1 A_2	E_1 E_2	D_1 D_2
Resistance in ohms			

Motor on no load test

Voltage	*Current*	*Speed*	*Accelerating time.*	*Coasting time*

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Precautions

(i) Ensure that no bolt, nut or washer is missing
(ii) Ensure that the leads are so routed that they are not entangled by fan or brush gear
(iii) Ensure that kerosene does not come in contact with electrical winding while cleaning metal parts
(iv) Ensure what the bearings are free from kerosene before putting grease.
(v) Do not over grease or under grease
(vi) Ensure proper spring tension on brushes

Questions

(i) How do you check rotor balance?
(ii) What is the cleaning agent for commutator?

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APPENDIX II

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